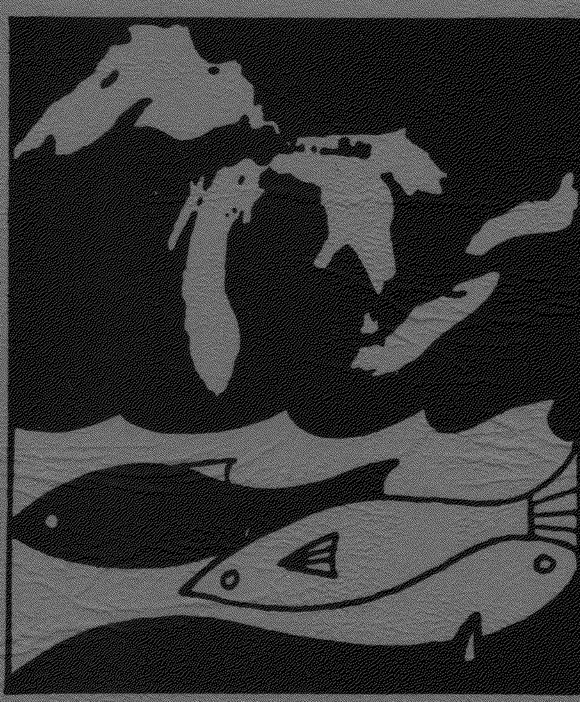
Proceedings

of the

Great Lakes Symposium



Annual Conference of the
National Marine Educators Association
Cleveland, Ohio

August 6, 1986

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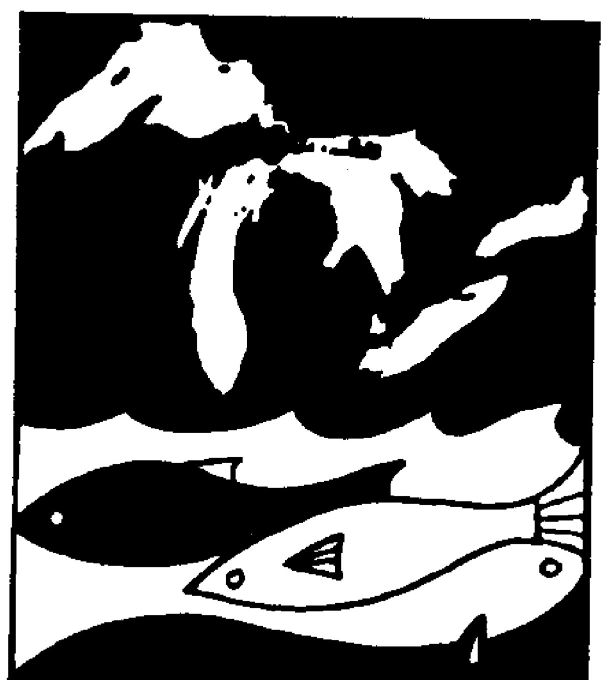

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PREFACE

The Great Lakes Symposium, an introductory portion of the 10th Annual Conference of the National Marine Educators Association (NMEA), was conceived as a means of drawing together for a single purpose a group of experts in areas that characterize the importance of the Great Lakes. Thus the scientists, historians, resource managers, policy analysts and policy makers represented by this group reflect the scientific, historical, environmental and political value of the North Coast to the United States and the world.

The purpose of the Symposium and this Proceedings volume is to present a body of basic information about the Great Lakes that is up to date, based on sound research, and interpreted by experts in the subjects involved. Such information is frequently difficult to locate, especially all in one reference, and equally difficult to decipher and evaluate. Educators and media communicators may avoid Great Lakes topics because of the elusive or esoteric nature of the information, or they may face a volume of library research that makes their handling of the topics subject to the limits of their research time.

We believe that information in hand, especially if well presented and applied to real needs, has a strong potential for use in communication and education. The presenters we have chosen were selected not only for their subject matter expertise but for their ability to communicate to the public as well. With the vitality and interest apparent in this work, they have provided a substantial information base about where the Great Lakes have been and what their future may be. This volume is a beginning set of answers for what we hope will be a growing interest among educators and communicators to learn and tell more about the Great Lakes.

There is a great deal more to tell. The story of the importance of the Great Lakes does not end at the back cover of the Proceedings or the close of the Symposium. It is a personal story, not only for those who share in the immediate grandeur of the lakes, but for every world citizen who shares the freshwater birthright. As stewards of the world of water, we can do no less than stand in awe of the resource portrayed here and pledge ourselves to its wise management in decades to come.

Rosanne W. Fortner

Rosanne W. Fortner,
Editor

CONTRIBUTORS TO THE GREAT LAKES SYMPOSIUM

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The Honorable Jim Bradley, MPP for St. Catharines, is Minister of the Environment for the Province of Ontario, Canada. He was first elected to the Ontario Legislature in 1977 after serving seven years on St. Catharines City Council. He has been Opposition Critic for Correction Services and Consumer and Commercial Relations and has served as a member of the Public Accounts, Justice, Social Development, General Government, Resources Development, and Hydro Affairs Committees. In municipal government, he was a member of the Board of Governors for St. Catharines General Hospital, the St. Catharines Transit Commission and Library Board, the Niagara District Airport Commission and the Regional Housing Advisory Board. Mr. Bradley was a teacher from 1967 to 1977 with Lincoln Board of Education. He is a member of the Ontario Public School Teachers' Federation, and has served on the Federation's executive. He is Opposition Deputy House Leader and Education Critic.

Lee Botts is an environmental consultant in Chicago. Among her current projects are analyzing how Chicago deals with the environment, working with the Chicago City Council on Energy and the Environment, consulting with National Geographic on a Great Lakes article to be published in 1987, and helping with Citizen's Review for a Great Lakes Water Agreement. Ms. Botts has been concerned about Great Lakes issues for some time, first as a volunteer citizen, then as staff for citizen groups, finally as a professional in the field. In 1970 she helped to organize the Lake Michigan Federation; in 1975-78 she worked for the USEPA. In 1978 President Carter appointed her as Chairperson of the Great Lakes Basin Commission. From 1981 to 1986 Ms. Botts was a research assistant on Great Lakes issues for the Center for Urban Affairs and Policy Research at Northwestern University, a position from which she is currently on leave. She received a B.S. degree from Oklahoma State University.

Charles Carter received his Ph.D. from Johns Hopkins University and worked as a scientist for the Ohio Geological Survey for ten years. He has been a Professor of Geology at the University of Akron since 1982. Dr. Carter's specialties are coastal geology, sedimentology and stratigraphy. He takes a special interest in the historic geological changes that the Lake Erie coastline has undergone.

Thomas E. Croley II received his B.C.E. and M.S. degrees from Ohio State University and his Ph.D. degree from Colorado State University in Civil Engineering with specialty in hydrology in 1969, 1970, and 1972, respectively. He worked on water resources systems problems for nine years as a professor and research engineer at the University of Iowa's Institute of Hydraulic Research, including work in New Zealand on surface runoff kinematics at the University of Canterbury and Lincoln College. He published a series of books on the use of calculators and small computers in hydrology and hydraulics as well as about 50 other referred articles on surface hydrology and water resources systems analysis. In 1980, he joined the Great Lakes Environmental Research Laboratory's Hydrology Group to develop rainfall-runoff models for each of the Great Lake basins. These models are part of his recently completed near real-time lake-level forecast package used both for research simulations and operational forecasting on the Laurentian Great Lakes as well as other large lakes systems.

Jane L. Forsyth is Professor of Geology at Bowling Green State University and is a well-known lecturer on the geology of Ohio. She authored a popular report on the physical features of Lake Erie and Ohio's northwestern shores in 1968 for the Toledo Regional Area planning office and prepared a guidebook on the geology of the Lake Erie islands and adjacent shores for Michigan geologists in 1971 (Michigan Basin Geological Society). In addition to her teaching, lecturing, and research in geology, she served on both the Ohio Geological Survey and as Editor-in-Chief of the Ohio Journal of Science for 10 years, has twice been vice-president for Geology in the Ohio Academy of Science, and was selected by Governor Rhodes, and now also by Governor Celeste, to serve on the state's Natural Areas Council. She is also active in the Ohio Chapter of The Nature Conservancy. Dr. Forsyth obtained her Ph.D. from The Ohio State University in Glacial Geology.

Rosanne W. Fortner is an Associate Professor in the School of Natural Resources at The Ohio State University. She is responsible for instruction and research in Environmental Communications. Since 1978 she has been involved as a curriculum developer and teacher educator in the Ohio Sea Grant Education Program. Having served as a member of the Board of Directors of NMEA and CAMEO, she is currently co-chair of the NMEA 10th annual conference. Her other activities include consulting editorships for The Journal of Environmental Education, The Ohio Journal of Science and Science Activities, as well as membership in a number of Great Lakes and environmental education organizations. Dr. Fortner received her B.S. in biology from West Virginia University, M.A. in earth sciences from Oregon State, and Ed.D. in science supervision from VPI&SU.

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Edwin J. Skoch holds a Ph.D. in Aquatic Zoology from The Ohio State University. He is a Professor of Biology at John Carroll University where he specializes in entomology and terrestrial and freshwater ecology. His research focuses on pollution biology, especially heavy metal toxicology in marine mammals. A lifelong resident of the Cleveland area, Dr. Skoch is eminently qualified to address his topic of life on the North Coast.

Andrew M. White is a Professor of Biology at John Carroll University. He has been active in fisheries research in Lake Erie since 1970. Interested in habitat and environmental effects on fish, his research has been conducted in many states, including Ohio, Indiana, Illinois, New York, Pennsylvania, Michigan and Texas. Past projects address such topics as dredging and its effects on fish for the Army Corps of Engineers and the causes of fish mortality at power plants. Dr. White is currently researching the causes of winter mortality in fish. Author of the book, Fishes of the Cleveland Metropolitan Area, he is also President-Elect of the Ohio Academy of Science. Dr. White received his Ph.D. from the Ohio State University in 1973.

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THESE ARE THE SWEETWATER SEAS

Lee Botts
Center for Urban Affairs and Policy Research
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When Jacques Cousteau calls the Great Lakes the cradle of the ocean, he acknowledges that the Great Lakes are the largest freshwater system on the globe. Each of the five separate but connected individual lakes is so large that they are known as inland seas. Like the oceans, the Great Lakes are an international resource, dividing Canada and the United States as political jurisdictions but uniting them in joint resource management.

One-fifth the population of the United States and three-fifths of Canada's live in the Great Lakes region. The lakes supply drinking water to about 25 million people, as well as water for power production, recreation and manufacturing in eight states and two provinces. They are the reason North America is the only continent with ocean ports a thousand miles inland.

The lakes opened the interior of the continent to Europeans for trade and later for permanent settlement. As both countries developed, lumber, sandstone and steel from Great Lakes shores helped build cities and fish from the lakes helped feed them. The lakes are also the reason the Great Lakes region has so many great cities of its own and such a large part of the industrial capacity and agricultural production of North America. And they are beautiful, with a majesty no body of water achieves when you can see to the other side.

Collectively the Great Lakes contain one-fifth of the world supply of fresh surface water, so much that the quantity is usually expressed in cubic miles. Lake Michigan alone holds over 1,100 cubic miles (4,900 cubic kilometers) of water. It would require a square tank that covers the United States from the Mississippi River to the east coast and reaches the same distance into the stratosphere to hold the water from just this one Great Lake.

All the Great Lakes are huge storage reservoirs of fresh water, with narrow connecting channels and only a small outlet to the ocean. Each year only about 1 percent of the water in the lakes flows out the St. Lawrence to the Atlantic. Appreciation of the Great Lakes requires understanding of how the size and the closed nature of the system have made these sweetwater seas especially vulnerable to environmental damage and how the damage has occurred.

In addition to contributing to national wealth, the Great Lakes have provided an early warning system for global environmental problems and an unmatched example of success in resource management across an international border. The lessons cover eutrophication, atmospheric transport of pollutants and bioaccumulation of toxic chemicals in the food chain. Today the binational community committed to protection of the lakes is working to apply the concept of an ecosystem approach to management.

An Ecosystem Approach to Management

The classic definition of an ecosystem is a complex of physical resources and the living organisms that depend on them. Ecosystem stability depends on evolution of a balance between physical resources and the biological community. The community maintains itself by adapting to the constraints and opportunities provided by available space, energy and food. The ecosystem approach assumes that man is part of and must adapt to the limits of the ecosystem in which he lives.

In the past 200 years human activities have caused fundamental change in the Great Lakes ecosystem that evolved during the 10,000 years after glaciers left the lakes behind. The forces that shaped the Great Lakes region began eons before the glaciers arrived.

How the Lakes Were Formed

In the Precambrian era about 4 billion years ago, geologic forces laid down the bedrock of the Great Lakes watershed in three distinct regions. To the north is the Canadian, or Laurentian, shield, where mostly thin soils lay over granite. Evergreen and conifer forests dominate the Upper Great Lakes region around Lake Superior, Huron and northern Lake Michigan.

In the central lowlands to the south, thick, fertile soils are layered over limestone in the lower Great Lakes region around Ontario, Erie and southern Lake Michigan. The lowlands have broad flood plains. The original hardwood forests dominated by oak, maple and beech mixed with white pine have generally been replaced by agriculture, industry and urban development. The third region is the wide flat valley of the St. Lawrence River that is the outlet of the Great Lakes to the Atlantic.

At least four times glaciers advanced south over North America and retreated, the last one only about 10,000 years ago. Each time melting filled deep basins gouged out by the glaciers. The Great Lakes watershed was finally formed as we know it today only about 2,000 years ago. In some places the land is still rebounding from the weight of ice.

The region has thousands of smaller lakes in addition to the Great Lakes. Although about two-thirds of the original wetlands have been drained or filled, many swamps, bogs and fens still characterize the water-rich land. One of the influences on the Great Lakes is that they are fed by hundreds of small tributaries that flow through many different kinds of soils and land uses. The lakes are so large that they modify the climate.

The Great Lakes Hydrologic System

The most distinctive feature of the Great Lakes watershed is the high proportion of water-covered areas to land. The Great Lakes watershed contains about 295,000 square miles (764,051 sq km), with about one-third or 95,000 square miles (246,000 sq km) covered by the Great Lakes themselves.

The long shoreline of the Great Lakes enhances the influence of land over the lakes. The 9,400 miles (15,150 km) of shoreline is longer than the United States coastline on the Atlantic and the Gulf of Mexico combined.

The lakes store heat as well as water. Both moisture in the air above the lakes and the heat they exchange with the atmosphere affect the climate. It is cooler in summer and warmer in winter near a Great Lake. Retention of heat lengthens the frost-free season and is the reason fruit is grown near Lakes Michigan, Ontario and Erie.

Winter and summer, the weather is more changeable because cold fronts from the Arctic and warm fronts from the Pacific and the Gulf confront each other so often in the moisture-laden atmosphere over the lakes. The moisture in the atmosphere provides many humid days in summer and heavy snowfalls in the lee of the lakes.

The long term average annual precipitation is about 31 inches (77 cm.), less at the western edge of the basin and more on the east. Variations in precipitation and temperature are the chief reasons for fluctuations in lake levels, with both more water supply and less evaporation during the wetter, colder periods when lake levels rise. While changes in lake levels affect shoreline development severely, the fluctuations of several feet are small in relation to the volume of water. All of the Great Lakes are part of a single hydrologic system but each one is different.

The system begins in Lake Superior, given its name by the French because it is the highest above sea level, about 602 feet (180 m), with the reference point at Father Point, Quebec. Superior is all superlatives, the largest in every way. It could hold as much water as all the rest of the lakes combined plus three more Lake Eries. It is the coldest and the deepest, up to 1,333 feet (399 m) with an average depth of about 500 feet (150 m) over all. Superior has the longest retention time for water, about 200 years. This lake is also still the cleanest, though its size and slow flushing time make it most vulnerable to permanent pollution.

Lake Huron and Lake Michigan share the same hydrologic system because their surfaces are at the same height above sea level, about 581 feet (177 m), and because they are connected through the broad Straits of Mackinac. Huron is the second largest of the five lakes and up to 750 feet (225 m) deep with an average of 194 feet (59 m). The flow retention time for Huron is only 22 years because of its relatively large outlet into the St. Clair River toward Lake Erie.

Lake Michigan is the third largest and the only Great Lake entirely within the United States. It is up to 925 feet (282 m) deep, with an average of 279 feet (85 m). Lake Michigan has a slow flushing time of 100 years because it us a cul de sac, receiving and discharging water to the system through the same outlet in the north. Like Superior, Michigan is more vulnerable to pollution because of its size and long retention time. Its problems are compounded by the largest concentration of industry and cities in the region around its southern end in the Milwaukee-Chicago-Gary metropolitan area.

Lake Erie is the shallowest of the lakes and holds the least water. Its fast flow through time of only three to five years makes it like a wide place in the Great Lakes river to the sea. Because of its small size and because of the concentration of row crop agriculture and numerous cities on its shores, Lake Erie was the first Great Lake to be affected over all by pollution. Yet Erie's fast flushing time assisted its dramatic response to clean-up of conventional pollution and its short water column makes is less vulnerable to toxic contamination.

Below Niagara Falls, Lake Ontario is downstream from all the other lakes and thus receives pollutants from upstream as well as its own watershed. It received large loadings of contaminants from the Niagara River, which is bordered by numerous hazardous waste landfills for the chemical industry that located in the area to use electricity produced at the Falls. Ontario is smaller in area but much deeper than Erie, 282 feet (86 m) on the average and up to 804 feet (245 m). The flow through time is only six years because it has the largest outlet of all the lakes in the St. Lawrence.

Change in the Great Lakes Ecosystem

When the first European explorers found the lakes in the 16th century, it is estimated that about 120 thousand people lived in the watershed that is home to more than 40 million Canadians and Americans now. Many of the native peoples depended on hunting and fishing. Those who planted crops moved on to a new location every few years, leaving the land to recover and waterways unchanged.

Most of the region was heavily forested, with deep grasslands in the few open areas, and travel was very difficult except by water. Streams ran clear and cold year round and seldom flooded because wetlands filtered the nutrients in slow runoff from the wooded land. Elk were the largest mammals, with bear, deer, wolves, beaver and large members of the cat family common throughout the region.

There were several hundred species of birds in great abundance. The Great Lakes, especially the north/south shores of Lake Michigan, are a continental flyway for migratory birds, with wetlands providing essential habitat for many species of waterfowl.

The Europeans also made little difference for the lakes in the first 200 years after their arrival. They lived in small settlements around the forts that protected the fur trade and the voyager traders traveled mainly on the natural waterways. Permanent changes began first in the east in the 18th century with removal of the forests for settlement and fields and damming of the streams to power grist mills.

The Great Lakes Fishery

Radisson, LaSalle and other early French explorers were amazed by the size, abundance, and number of species of fish in the Great Lakes. It is thought there were about 180 native species of fish, some now extinct, and many subspecies adapted to particular locations. Still, the lakes were relatively unproductive for their size, because of the low level of nutrients in the water, and the fishery was quite different than it is now.

It is believed there were many fewer individual fish in the lakes but that the average individual fish probably weighed 4 or 5 pounds (1.7 to 2.2 kg). Radisson marveled at six foot long pike. Century-old sturgeon that weighed up to 400 or 500 pounds (171 to 227 kg) may explain the old drawings of so-called sea monsters in the lakes. Several kinds of herring, whitefish and lake trout were abundant in open waters. Perch were found mainly in shallow bays where nutrient levels were higher.

But there were no carp, smelt, brown or rainbow trout, alewives, pink salmon, splake or the Pacific salmon now so prized by sports fishermen, the coho and chinook. Nor was there any sea lamprey, at least not above Niagara Falls. None of these fish so common today are native to the lakes, while a number of native species, like the blue pike and the longjawed cisco, are extinct.

The lamprey and the alewife, a small ocean herring, are believed to have invaded the lakes from the Atlantic through man-made canals. The smelt and pink salmon accidentally reached the lakes after being stocked elsewhere. The others, including carp, were deliberately introduced.

Scientists agree that restoration to the conditions that existed before the landscape and the lakes were changed by settlement and industrialization would be impossible. Yet protection of the integrity of the ecosystem for the future requires attention to how much rehabilitation and restoration can be accomplished and to whether there is agreement on what would be desirable. Overfishing, pollution and habitat loss as well as the advent of exotic species have all contributed to ecosystem change.

Changes in the Great Lakes Ecosystem

The temperature was raised and the character of streams changed as forests were removed from the banks and flows slowed by dams. Fishery biologists speculate that the warmer water gave an advantage over native species to the parasitic sea lamprey in streams where they spawn. The lamprey attacks large fish by attaching itself by its large mouth ringed with sharp teeth and feeding on the body fluids.

After the Northwest Ordinance opened the Great Lakes region to permanent settlement following the Revolutionary War, canals were built to improve transportation into the interior of the continent. It is believed the alewife and lamprey entered the Great Lakes through the Erie Canal and reached the upper lakes through the Welland Canal that was built to bypass Niagara Falls for navigation.

Both were present in Lake Erie by the mid-19th century but were not recognized as a threat until much later. The Great Lakes fishery was a major food source for the expanding cities through the century. Little notice was taken initially of fluctuating catches and decline of some species, because other desirable species always seemed to be available.

The peak commercial fishing years on the Great Lakes were from the 1860's to the turn of the century as lack of regulation, increasing markets and more efficient fishing equipment encouraged heedless harvesting. Sturgeon had become rare by 1900 because fishermen, who disliked the way the sturgeon's bony snouts tore their nets, piled them up like logs and burned them. By the time the value of sturgeon caviar was recognized, it was too late.

Today, sturgeon in the lakes are rare and small. Commercial fishing remained a major Great Lakes industry through World War II, but by the 1950's the lamprey had almost destroyed the lake trout in Michigan and Huron and other catches had declined drastically. Now the largest commercial catch in Lake Michigan is alewives for animal and chicken feed.

It is difficult to weigh the relative role of several factors in the decline of the value of the commercial fishery. In the United States, some species cannot be sold in interstate commerce because the concentrations of PCB's and certain other chemicals exceed levels considered safe by the Food and Drug Administration. The populations of other species are too small and increasingly state governments favor sport fishing over commercial fishing because they believe the economic return is higher.

In 1955, Canada and the United States established the Great Lakes Fishery Commission to find a way to control the lamprey. Since the early 1960's, two chemicals have been used to kill lamprey spawn in streams. The lamprey population has been reduced up to 90 per cent but total eradication is unlikely.

One concern is that the lamprey may be developing resistance to the lampricides. Another is that deliberate introduction of chemicals into the aquatic ecosystem should not be continued. A third is that, ironically, pollution control has extended the lamprey's intrusion into cleaned up rivers. Since water quality improved in the St. Louis River near Duluth in the 1970's, the walleye have returned but the dreaded lamprey has also begun spawning there in the farthest reach of the Great Lakes system.

The intrusion of the alewife and smelt also contributed to permanent change. The alewife is not well adapted to the Great Lakes and dies off in the spring. In Lake Michigan, the alewife population grew as the lamprey destroyed the top predator, the lake trout, leading to one of the best-remembered Great Lakes disasters. In 1967, thousands of tons of dead alewives clogged Chicago's drinking water intakes and made beaches all around the lake unusable all summer. The smell will never be forgotten. Public horror increased because of massive dieoff at the same time of waterbirds who contracted botulism by eating the rotting fish.

The depredations of even the tiny smelt were first recognized by commercial fishermen who observed that the smelt eat eggs and fry of other, more desirable fish. Debate continues over the relationship between species changes and degradation of water quality as factors in ecosystem change. Sport fishermen do not question the value of the deliberate introduction of salmon from the Pacific Northwest into the Great Lakes.

The coho and chinook salmon were introduced in the mid-1960's by fishery experts who reasoned that the alewife population could be reduced by new predators and the lake trout restored as the lamprey declined. The salmon thrived so well that by 1970 the enthusiasm felt by fishermen for the big fish was called coho fever. With return of the walleye to Lake Erie and salmon stocking in all the other lakes, sport fishing has developed as a major new industry in a region that has been losing others.

The State of Michigan officially promotes sport fishing over commercial fishing. Other states seek to promote both, but competition between sport and commercial fishing interests is growing. Some support fishing organizations are using their political power to advocate that efforts to restore the native lake trout be abandoned so that more money can be devoted to stocking the exotic salmon. With new appreciation for the many ways the Great Lakes ecosystem has been disturbed, biologists consider the future of all Great Lakes fisheries to be uncertain.

Although massive stocking of the lake trout has continued since the mid-1960's, the trout does not yet reproduce enough to sustain itself except in Lake Superior. The problem may be partly genetic, since many subspecies adapted to specific locations were lost. Research has shown that both reproduction and survival are affected by the presence of toxic contaminants such as PCB's and toxaphene. In any case, bioconcentration of persistent organic hydrocarbons makes the trout as well as the large salmon unsafe for human consumption in most places.

Furthermore, the alewife population has now been reduced so much that it no longer provides a sufficient forage base for the Pacific salmon, which, to the dismay of sport fishermen, are not growing as large now as they did in the early 1970's. Now the salmon seem to be turning to the smelt and to native herring and perch for food. Fishery management agencies are being urged to limit commercial fishing of native species to protect a forage base for the put-and-take salmon fishery. Lake Michigan, the sixth largest lake in the world, is so dependent on stocking that it is called the world's largest fishbowl. Public health advisories against consumption of various species are issued by every state and province and toxic contamination is now considered a potential threat to future use of the lakes for drinking water as well as to the Great Lakes fishery.

Degradation of Great Lakes Water Quality

The first pollution problems in the lakes were also observed by 1900, but they seemed to be localized and caused no general concern. As lumbering spread across the Great Lakes region, sawdust clogged the mouths of tributaries, destroying habitat and increasing biochemical oxygen demand (BOD) as it decomposed. Increased soil erosion and runoff as the land was stripped of vegetation and plowed added silt to the pollution load that tributaries delivered to the lakes. Today, agricultural runoff is a source of pesticides as well as nutrients.

Near the rapidly growing cities, industrial wastes and untreated sewage caused fouled harbors and nearshore waters, adding disease-causing bacteria to high BOD problems. Chicago was the first city to act to protect its Great Lake water supply.

After an estimated 15 per cent of the city's population died in epidemics of cholera and typhoid from 1885 to 1887, the flow of the Chicago River was reversed to carry sewage effluent away from Lake Michigan into the Illinois and Mississippi rivers. The action protected the lake but was an early example of displacement rather than elimination of wastes. Congress passed the 1899 Refuse Act to stop discharge of industrial wastes but vigorous enforcement of this law did not begin until 1969 and localized pollution continued to grow in the Great Lakes.

The Boundary Waters Treaty of 1909 and the IJC

In 1909 Canada and the United States negotiated the Boundary Waters Treaty to provide a peaceful system for resolving disputes and for making cooperative decisions for all the waterways that cross their common border. The treaty established the International Joint Commission (IJC) as a uniquely independent agency that advises the governments.

Three members of the IJC are appointed for each side and they are supposed to carry out their duties as individuals without regard for national concerns. The duties of the IJC include studies on problems by reference, or request, from the governments. The IJC also informs the governments about problems that need attention, but it has limited authority to initiate a study on its own. Nor can the IJC initiate actions to solve problems unless directed to do so by the governments.

By 1919, the IJC reported to the governments that serious degradation of water quality was occurring in more and more locations in the Great Lakes but no action was taken. By 1929, the first scientific report was made that decay of massive algae growths was causing depletion of oxygen in the western basin of Lake Erie.

Over the next decades oxygen depletion was observed in a larger area in Lake Erie every summer. About 1960, scientists reported that for the first time accelerated eutrophication threatened the future of a whole Great Lake. A reporter's interpretation that "Lake Erie is dying" alarmed a public that was growing increasingly concerned about air and water pollution generally.

The public concern provoked both governments to sign the Great Lakes Water Quality Agreement in 1972, with the IJC directed to oversee its implementation. Initially, the binational Great Lakes agreement emphasized reduction of phosphorus loadings to control eutrophication.

Eutrophication and the Great Lakes

The trophic status of a lake is a measure of its biological productivity. Nutrients and light are necessary to sustain life in water as they are for growth on land. Eutrophic waters are most productive, oligotrophic least productive, with mesotrophic somewhere between. Accelerated eutrophication in Lake Erie actually meant, then, more life rather than less, with more pollution-tolerant species becoming dominant.

The most obvious signs to the public were fewer walleye and many more perch, and turbid or cloudy water due to heavy algae growth, especially the long, slimy, exceedingly unpleasant algae called cladophora. The Great Lakes agreement stressed reduction of phosphorus loadings when scientists agreed that it is the limiting nutrient for the Great Lakes. The agreement called for a binational cleanup process to be carried out through the new Great Lakes Regional Office of the IJC, located in Windsor, Ontario, just across the river from Detroit.

The Great Lakes Water Quality Agreement

In the Great Lakes agreement, the governments of Canada and the United States agreed to work together and separately to achieve specified water quality objectives. The aim is both to clean up existing pollution and prevent continuing degradation. The process established by the agreement calls for remedial programs, research and monitoring. It also provides for accountability and flexibility to modify the objectives as conditions change or as new information is developed.

Two binational boards of experts are called for, the Water Quality Board and the Science Advisory Board. Members of the Water Quality Board represent environmental management agencies while members of the Science Advisory Board include academic experts as well as staff of research agencies. Both assist accountability by making annual reports to the IJC on progress toward meeting agreement objectives.

The agreement recognizes differences in the two countries by allowing remedial programs to be carried out under their own laws. In Canada, the province has primary responsibility for environmental management. Thus there is a Canada-Ontario Agreement that the province will apply the Great Lakes water quality objectives in its pollution control programs. In the United States, the federal government set minimum national standards under the Clean Water Act and the Environmental Protection Agency has the lead responsibility for meeting Great Lakes water quality objectives.

For phosphorus, the 1972 objective was no more than 1 mg. per liter in effluents discharged directly into Great Lakes waters. Control measures included expansion of sewage treatment capacity and reduction of phosphates in detergents.

Both countries established new Great Lakes research programs to meet commitments under the agreement. Canada has its Centre of Inland Waters and the United States has special Great Lakes programs and laboratories under EPA, the National Oceanic and Atmospheric Administration (NOAA), and the Army Corps of Engineers, with other agencies participating as needed. A reference from the governments called for a cooperative Land Use Activities Reference Group study (PLUARG) as the first major effort.

The study from 1973 to 1976 was designed to answer three questions: How much Great Lakes pollution is caused by land runoff? Where is it occurring? What should be done about it? The PLUARG report identified agricultural runoff as the source for about half the phosphorus loading of Lake Erie and led to demonstration projects for conservation tillage. What is now a national movement for conservation tillage to reduce soil erosion was begun to improve Great Lakes water quality. The study also identified the atmosphere as another major diffuse source of pollution to the lakes, particularly toxic substances.

Toxic Contamination

By 1976, the monitoring reports and results of research had confirmed high levels of many toxic chemicals and heavy metals in the lakes as well as long range transport through the atmosphere. Great Lakes states had banned DDT after scientists demonstrated in 1968 how the pesticide bioaccumulated in the food chain of Lake Michigan. In 1971, fishery biologists who were monitoring decline of DDT levels in fish discovered high levels of polychlorinated biphenyls (PCB's), a discovery that led to a ban on manufacture of PCB's in the Toxic Substances Control Act. In 1975, high concentrations of PCB's were found in lake trout in a small lake on Isle Royale, a wilderness national park in northern Lake Superior far from any possible direct source.

When results of the 1972 agreement were reviewed after five years by the governments, a second agreement was developed and signed in 1978. The new agreement added a call for an ecosystem approach to management and a virtual zero discharge of toxic substances as objectives.

For phosphorus, the 1978 agreement introduced the concept of mass balance as a basis for control by calling for individual target loadings for each lake. The target loading is set to reverse eutrophication. Today, reduced algae growths in most Great Lakes locations and return of the walleye to Lake Erie, to the St. Louis River near Duluth and to the Fox River that flows into Green Bay are all considered signs of reduced eutrophication. The signs continue to improve in the lakes themselves.

Comparable progress has not been made in control of toxic contamination, but I believe that experience in the Great Lakes is again showing the way for addressing a serious, complex, and most difficult environmental problem. The National Academy of Sciences in the United States and the Royal Academy of Canada recently endorsed the need for an ecosystem approach to management in their joint review of progress toward meeting the objectives of the 1978 Great Lakes agreement. Better understanding of the sources and fates of toxic contaminants in the Great Lakes has set the stage for an ecosystem approach in remedial programs, with ecological integrity rather than only reduced levels of specific pollutants as the goal.

A New Great Lakes Strategy

The new strategy for control of toxic contamination that is emerging from the Great Lakes is based on a mass balance approach. This approach seeks to identify all sources and to control toxic substances to levels that do not affect the health and well being of organisms, the definition of toxic in the Great Lakes agreement. It takes into account bioconcentration as the process by which contaminants present in very low levels in water bioaccumulate to dangerous levels that affect both life in the lake and other organisms, including humans, at the top of the food chain.

To date, over 1,000 chemicals and heavy metals have been identified in the Great Lakes ecosystem, in the water, in sediments, or in fish. Persistent organic chemicals such as PCB's can concentrate up to levels up to a million times greater in large salmon and trout than in the water. High rates of tumors in fish and birth defects in herring, gulls and cormorants demonstrate consequences of toxic contamination. Long term epidemiological studies of humans with high levels of PCB's in their bodies because they eat Great Lakes fish are showing potential consequences for human exposure. Babies born to and breast fed by mothers with high concentrations of PCB's in their fat and blood are smaller on the average at birth and show subtle neurological signs of developmental disturbance.

We now know that sources of toxic contaminants into the lakes include the atmosphere and sediments as well as direct discharges and land runoff. Four-fifths of the loading of toxic substances to Lake Superior and half to Lake Michigan is by atmospheric deposition. Sources to the atmosphere include incineration, evaporation from industrial and sewage treatment systems, and evaporation from agricultural operations. In recent years scientists have learned that PCB's and other volatile organic chemicals evaporate from the surface of the water and are passed through the water column back into the atmosphere in gasses excreted by bottom feeding organisms.

Chemicals are reaching the lakes through groundwater from hazardous waste landfills in connecting channels such as the Niagara and St. Clair rivers. They do not remain settled out in sediments but can be resuspended by wave action due to passing ships or storms, or ingested and excreted. The size and closed nature of the Great Lakes make them a sink for toxic substances. The lesson of the lakes is that, if it is happening in the Great Lakes, it is happening in the biosphere.

Conclusion

The story of the Great Lakes is complex and I have omitted many details of how the Great Lakes community is learning to apply an ecosystem approach to management of this huge resource. Whether we will succeed as well with the more difficult problem of toxic contamination as we have with eutrophication remains to be seen.

Still, scientists tell me that the Great Lakes achievement with phosphorus control in such a large system in so many jurisdictions by so many different measures is unmatched anywhere in the world. Surely we should learn from this success and continue the Great Lakes Water Quality Agreement to carry out remedial programs, research and monitoring across the border we share with Canada.

I remain confident that, with sufficient understanding, the public will support whatever is necessary for control of toxic contamination as well. We welcome you as educators who will join in fostering the understanding on which the future of the sweetwater seas, and the biosphere, depends.

THE HONOURABLE JIM BRADLEY
ONTARIO MINISTER OF THE ENVIRONMENT
REMARKS TO THE NATIONAL MARINE EDUCATION ASSOCIATION
ANNUAL CONFERENCE

AUGUST 6, 1986

Good afternoon.

It is a pleasure to be asked to speak on a topic of such great importance to both our countries. It is particularly gratifying to see a distinguished group of educators taking such an interest in the Great Lakes. The interest we all show in the well-being of this important part of the common heritage of the United States and Canada is essential if we are to preserve this valuable water resource.

I come here today to speak to you not just as Ontario's Minister of the Environment, but as a fellow teacher. Before politics drew me from the classroom, I spent ten years teaching in my province.

It is as a colleague, then, that I urge you to take a message back to your classrooms. We must mount a concerted attack on the pollution that threatens the quality of our Great Lakes water if we are to preserve this valuable legacy for our own benefit and for the pleasure and prosperity of our children.

As a concerned citizen of not just Ontario, but of North America, I have made that commitment. As a politician fortunate enough to be part of a government committed to protecting the environment, I have embarked on an ambitious program to improve the quality of the precious waters that are so crucial to the economic well-being of my province and the states in the Great Lakes Basin.

Today, I will outline what Ontario is doing to fulfill its commitment. But first let me put the need for action in perspective.

The Great Lakes region is a colorful and cherished part of North American history. The ancient peoples of this continent gravitated to this region, as did many of the explorers and settlers who followed them. Since the beginning of European settlement, life in Canada has focused on the Great Lakes - St. Lawrence River system. To Canadians, however, these waterways are more than just history and heritage. They shape the industrial heart of our nation.

Let us consider what the Great Lakes mean in human terms. Almost 40 million people on both sides of our common border live in the Great Lakes Basin. Sixty per cent of Ontario's population lives in a handful of major urban centres within the Great Lakes watershed, including Toronto -- Canada's largest city and the seat of our provincial government. Water from the Great Lakes provides the drinking supply for one-half of the population of Ontario. In fact, one half of Canada's entire gross national product stems directly from the Great Lakes basin -- in the form of fishing, transportation, manufacturing and hydroelectric generating plants.

You can see, then, that the Great Lakes are an integral part of this continent's capacity to produce wealth. They are highways of water, carrying cargo economically. They quench the thirst of our citizens and industries. They give us electricity. Their secluded beauty spots, teeming waters and busy beaches are the basis of a vibrant tourism industry.

But these are troubled waters, too. For too long, we treated these magnificent lakes with cavalier indifference, thinking that somehow these gigantic bodies of water could absorb without effect our industrial wastes, our municipal sewage and our ever-increasing demands. This is the largest fresh water system in the world -- and indeed represents some 18 per cent of the world's fresh water supply -- but it is not immune to the insults and injuries a modern industrialized society can unthinkingly deal out.

Unfortunately, the signs of trouble are all too clear, and all too foreboding. Recently, a study prepared by the Royal Society of Canada and the U.S. National Research Council stated (and I quote),

> "The human population living in the Great Lakes Basin is exposed to appreciably more toxic chemical burden than other human populations in similarly large regions of North America."
> (end of quote)

This is a strong warning . . . and a challenge to reverse the trend of degradation and restore the Great Lakes system to environmental health.

The Canadian-U.S. International Joint Commission, which oversees the 1978 Great Lakes Water Quality Agreement between our two countries, has said persistent toxic substances remain the principal issue confronting the Great Lakes. Scientists believe more than 1,000 chemicals are in these waters.

I am not advocating a reduction in industrial activity or a massive change in the prosperous way of life the Great Lakes have helped foster. I am talking about simple prudence -- we must control pollution in the Great Lakes system to safeguard our own health and wealth.

My personal goal is the virtual elimination of persistent toxic chemicals in the Great Lakes Basin. It is a distant goal, with many stops along the way, but that is where we are going.

Our citizens are more concerned than ever about environmental issues. It is a heartening sign, and indicates the time is now right to accellerate the political process of cleaning up the Great Lakes Basin.

That is precisely what we are doing in Ontario. We are a young government, little more than a year old. We have had to overcome the inertia engendered by our predecessors who pampered a herd of sacred cows. In our short tenure, we have shown the public and industry that the time for coasting is over, and the day of clean-up and reform is at hand.

That is why I say my goal is the virtual elimination of persistent toxic substances from the Great Lakes. It is with that goal in mind that my ministry is breaking new ground.

Let me give you an example that illustrates our commitment to solving this complex problem.

Shortly after I became Ontario's Environment Minister last summer, we pursued the serious pollution problems in the St. Clair River region. Following a spill of the cleaning solvent perchloroethylene into the river by Dow Chemical, a tarry substance was discovered on the river bed. Examination and testing of this so-called blob revealed the presence of dioxins and a fistful of other toxic chemicals.

As a result, we began a careful and detailed program of drinking water monitoring in this petrochemical manufacturing region. Octadioxin was discovered. Perchloroethylene was also found in treated drinking water. Scientists and medical experts assured us the levels of both substances were within health-related guidelines set by Ontario, Health and Welfare Canada and the World Health organization.

This may be reassuring in the short-term, but I am committed to wiping toxic contaminants from the St. Clair and Ontario's other water systems. I regard the problems in the St. Clair River as an opportunity to develop a comprehensive program of tough reforms to measure and reduce chemical discharges into all the province's waterways.

My ministry is developing regulations that will require both industries and municipalities to monitor and report to my ministry on discharge activities. Abatement measures will follow close behind.

We are sampling and analyzing drinking water supplies around the province for more than 100 potential contaminants.

And we are employing the most up-to-date technology to clean up the areas that require immediate action.

Soon, these measures will be in effect throughout Ontario's portion of the Great Lakes Basin. Where closer scrutiny of discharges is warranted, we will do so. Where more manpower is needed to handle special problems, we will provide it. Not just in the area we call The Chemical Valley, but wherever contaminants are found.

There is another side to tougher regulations. They must be coupled with penalties that deter polluters. To that end, I am dedicated to showing polluters that the days of a slap on the wrist for assaulting our environment are over.

We are establishing a new penalty structure that will allow flagrant polluters to be sentenced to jail for as much as a year. Fines will be heavier, and every day of illegal pollution will be considered a separate offence. There will be provision for capturing ill-gotten gains from pollution.

The environment will benefit from these penalty bump-ups, and so will the vast majority of our industries. These corporations invest considerable capital to control pollution and meet the public's expectations. They should not be put at a competitive disadvantage to the few mavericks and recalcitrants which seek to squeeze private benefit from dirty production methods. I intend to take the profit out of pollution.

These two measures will help give the Great Lakes a chance to revitalize themselves. By eliminating pollution at the source, we can look forward to a day when these huge bodies of water will begin to heal themselves. The lakes have served us well, and we must serve them equally as well. That is why, for a moment, I would like to speak to you as a Canadian speaking to Americans.

I do not have to tell those of you from Michigan, Minnesota, Wisconsin or New York State how important the Great Lakes are to your well being. And here in Cleveland -- whose front doorstep is Lake Erie -- the economic, cultural, and recreational impact of these lakes are ever present.

But I ask those who have come here from regions far removed from the Great Lakes to remember that these waters are as important to your country as they are to ours -- and they deserve the care of both Canada and the United States.

The imaginary line that cuts through Lake Superior, Lake Huron, Lake Erie and Lake Ontario is our common border. But map lines do not stop the flow of water between our countries. Nor can it stop the flow of pollutants.

We have seen evidence of that in the Niagara River area. The contamination problem there is severe. Dioxins have been identified at several dump sites along the U.S. side of the River.

We recently learned of dioxin levels at the 102nd Street dump adjacent to the Niagara River some 630 greater than the amount requiring federal action. Yet the Environmental Protection Agency has not ordered the removal of these dangerous chemicals. Its capping and containment approach to hazardous waste sites is adequate only as a short-term, stop-gap measure.

It is not a permanent solution. Only excavation of the sites and destruction of the toxics will provide long-term security for the water supply which millions of our citizens rely upon. This and several other direct threats to the Niagara River, which flows into Lake Ontario and provides drinking water for four million Canadians, must be removed.

Consider the costs of not removing these contaminants. A recent study by our federal Inland Waters Directorate tells us the social, health and environmental toll could be staggering -- as much as 172 million dollars per year.

That includes the cost of additional water treatment facilities around Lake Ontario, damage to the Lake Ontario fishery, the effect on almost three million angler-days spent fishing in the lake each year, social and health costs, and depressed real estate values.

We know that Canada will be faced with the major portion of these costs. We do not think it is fair that we might be required to pay such a high price -- especially when we know there are ways of reducing the risk of this potential financial burden and environmental disaster.

We know, too, that New York State does not want to pay that price. That is why a meaningful, comprehensive plan to curb chemical pollution in the Niagara River is such a high priority on both sides of the border.

Congress must be convinced that we, on both sides of the border, need its commitment to funding and quick action on a Niagara clean-up.

It is imperative that we -- as countries, provinces, states and voters -- act together in our efforts to protect the environment.

We must all muster the political will to co-operate and act forcefully on an issue that strikes at us all.

If we can co-operate on the Great Lakes, we can co-operate on every aspect of environmental protection -- including tackling the serious problem of acid rain.

Congress and President Reagan must also be convinced to make an all-out assault on the sulphur emissions that are slowly killing rivers, streams and smaller lakes that lie in the Great Lakes Basin.

In Ontario, we have recently introduced the strongest measures against acid-rain-causing emissions ever undertaken in North America.

We call it Countdown Acid Rain. It requires drastic reductions in Ontario's sulphur dioxide emissions over the next eight years. The four major industrial polluters that are responsible for 80 per cent of these emissions in my province have been ordered to reduce them by 67 per cent by the year 1994.

As educators concerned with marine life, I'm sure you are aware of the disastrous effects of these emissions on our lakes and rivers -- and on your lakes and rivers. You may be interested to know that 50 per cent of the acid rain that affects Canada's eastern provinces originates in the United States. In fact, the United States contributes four times as much acid rain to Canada as we do to the United States.

We cannot erect border barriers against acid rain. We can only stop sulphur emissions at their sources, before they drift over the Great Lakes and into the waterways of my province. True, the Great Lakes hold up against acid rain because of the neutralizing effects of their limestone deposits. But the aquatic life in streams, rivers and lakes that feed into them does not.

Acid rain abatement must become a priority. Recently, the governments of our countries endorsed a report by Canadian and American envoys that recognizes acid rain as a problem caused by pollution. It is a step in the right direction, but hardly a monumental achievement.

As a result of that report, President Reagan is expected to commit funds to a $5-billion joint industry and government program to study acid rain abatement technology in the United States. However, we need more than studies on the part of Americans. We need a federal law to cut acid rain pollution -- now.

Earlier, I spoke of my role as a citizen of not just Canada or Ontario, but of North America. Acid rain, Great Lakes contamination -- and indeed pollution of any kind -- are problems that know no borders. Accordingly, our determination to ensure the health of our environment and the safety of our peoples should also know no borders.

I have outlined Ontario's commitment to ridding the Great Lakes system of dangerous chemicals and cutting down on harmful sulphur dioxide emissions. Let me say again that I will not be satisfied with anything less than the virtual elimination of contaminants from the waters of the Great Lakes Basin, and drastic cutbacks in acid rain to levels which all but the most sensitive waterways can tolerate.

Let me stress once more that there is no point in simply cleaning up problems that already exist. Yes, we must clean up. But we must also put in place a systematic reform of pollution control to halt the accumulation of persistent toxics and prevent future emergencies.

That is why I remind you that you are the teachers of the coming generation of voters, politicians, and concerned -- I hope -- citizens. You are aware of how crucial clean waters are to our future, and that the fight to protect them must be carried on by your students. Please make these environmental facts of life part of your message to your students.

Let us all work together to save the Great Lakes, the small lakes, the rivers and the streams of North America.

Thank you.

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A HISTORY OF GREAT LAKES SHIPPING

By Alexander C. Meakin

The history of Great Lakes shipping is a broad subject. It begins with primitive dugout canoes, and stretches across the years to modern bulk carriers that are so large that it is impossible for them to pass through any of the canals and rivers that link the lakes to the oceans. Thus, in fact, they are literally locked into the lakes.

In attempting to understand the role of shipping from the perspective of history, it can be said that the upper mid-west and central Canada were developed because of the Great Lakes. The exploration of the central portion of North America was carried out largely by water. Most of the early settlers entered the region by water. And the development of heavy industry in North America's heartland was largely because of the concentrations of minerals and other raw materials in the region itself. The relatively low cost transportation of such materials over the lakes led to the development of the largest part of the American and Canadian steel industries, which, in turn, were the backbone of our two nation's economies until the recent economic recession. Thus, in a very real way, the Great Lakes were the lifeline that supported the development of our two nations over a span of almost a century and a half.

The vessels that were developed over that period were propelled by both sail and steam, as well as more modern types of engines in recent years. They have included the development of technological features which in some cases have spread into world wide use.

A brief survey of various vessel types and their development will give a broader insight into the role of the lakes in the moving of people and cargoes through the years. Perhaps the best place to begin, is to go back to the very beginning of civilization in North America and examine vessels used by primitive peoples.

Over a period of many centuries, the heavy wooden dugout canoes of the earliest Indians evolved into small hide and bark covered canoes. These lighter canoes were quite efficient in relation to what they could carry, and in relation to the effort needed to move them from place to place. They, in turn, led to a class of somewhat larger canoes which were used by the Indians for the movement of animals killed by hunting parties. Some of this type of canoe were also used for the movement of war parties, hence the name War Canoe.

The ultimate in small canoes were those covered with birch bark. They were very light in weight, and could be moved with very little effort. It is generally believed that the finest canoes of this type were those developed by the Algonquian tribes.

Many of the earlier explorers an missionaries also traveled by canoe. Most of them were of the larger varieties. A 25 foot canoe could carry about a ton and a half of cargo, plus a seven or eight man crew.

The legendary voyageurs further developed the canoe into a highly efficient type of cargo vessel. Some of these were 35 to 40 feet in length, and could carry a crew of fourteen to sixteen, plus a tremendous quantity of furs or other cargo.

Probably the first new type of vessel developed especially to meet the needs of Great Lakes commerce was what, in later years, came to be known as a Mackinaw Boat. Originated by the French, it continued in use well into the present century. Built entirely of wood, in later years it was double ended. Many carried sails, and some had center boards for stability. They were used largely on the upper lakes and for every imaginable purpose, including commercial fishing.

The first large sailing vessel to be built for service on the lakes was the Griffon which was built by the explorer LaSalle in 1679. As time went on, sailing vessels of many different types were built, both for the movement of people, and for various commercial cargoes as well. Some of these vessels reflected certain characteristics associated with particular cargoes. Others reflected the skills, or lack thereof, of their builders. Thus, vessels built in one port were often quite different from those built elsewhere.

As sailing vessels continued to be built over the years, they gradually evolved into a few basic or standard designs as far as their rig was concerned. In turn, some such as the David Dows were truly gigantic. Having five masts, and being 265' in length, and displacing 1,419 tons, she was large even by ocean standards. Although sailing vessels continued to be built into the later years of the nineteenth century, the development of steam vessels parallelled the development and use of sail.

The first commercial steamer above Niagara was the Walk-In-The-Water of 1818. She was built in Black Rock, N.Y., near the present city of Buffalo. She could make the run from Buffalo to Detroit in 44 hours! The sidewheeler Michigan of 1833 marked a major change in vessel design. For the first time passenger accommodations were placed above the main deck.

Many of the earlier sidewheelers, as well as some of the larger sailing vessels in use during the first half of the nineteenth century, carried thousands upon thousands of settlers to the new communities then springing up along the shores of the lakes. In contrast to the settlement of other areas of the mid-west and far west, the cities of the Great Lakes basin received most of their early settlers by water, rather than by covered wagon.

With the opening of the North American heartland for settlement following the War of 1812, large quantities of household goods and raw materials for light industry began to be moved by ship across the waters of the lakes. Similarly, agricultural products, fish, minerals and timber were moved across the lakes as a first link in their transportation to other regions of Canada and the United States.

With the discovery of large quantities of copper in the Upper Peninsula of Michigan, that metal became a major cargo on the lakes for many years.

Soon after the close of the original exploration of the lakes region, the shipment of timber became a major operation in certain areas, particularly on Lake Ontario and the St. Lawrence River. For over a century the British Navy looked to both Canada and the United States for much of the timber used for the construction of its vessels. In later years lumber in rough form became the largest commodity moved on the lakes. By the early years of the present century the volume of lumber moved began to drop off in volume. At the same time, the movement of large "rafts" of pulp wood continued to be a major shipping activity until about the time of World War II.

With the discovery of iron ore in the Upper Peninsula of Michigan, and later in Minnesota, the development of the iron and steel industry in the United States and Canada entered a new era. And the lakes became the main route for the movement of the ore to the new steel making centers. Over the span of only a few decades iron ore became the major cargo moving on the lakes. As time went on, this ore, together with the coal and limestone used to make steel, became the life blood of North America's heavy industry, and the economies of both nations. The importance of iron ore in this respect continued until the nineteen eighties when the entire steel industry collapsed. As recently as the nineteen seventies, the locks at Sault Ste. Marie, largely because of the volume of iron ore, annually passed more cargo in an eight and a half month season, than did the Panama, Suez, and Kiel canals combined over a full twelve months.

The handling of bulk minerals and ore was originally done with barrels or kegs. As specialized loading and unloading equipment was developed, such cargoes began to be handled in bulk. The first vessel especially designed and built for the moving of such bulk cargo was the wooden steamer R. J. Hackett which was built in Cleveland in 1869. An interesting peripheral development took place in relation to the Hackett. Several years after she was built, a consort, the Forest City, was built to be towed by the Hackett, thus increasing the capacity of the steamer. The barge carried a limited suit of sails for propulsion in the event that she was let loose or broke loose from the towing steamer. This use of two barges became quite widespread as time went on. Many of the older wooden schooners finished out their careers as tow barges. In later years a number of steel barges were built for such service. The use of consorts continued on a limited basis until shortly after World War II.

The use of steel in the construction of vessels was in full swing by the end of the eighteen eighties. A few of the earlier steel framed vessels were sheathed with lumber, an effort that sought to utilize the particular values of both materials.

One of the most unique developments in vessel design was that of the so-called whalebacks or pig boats. They were used for the movement of bulk cargo. Designed and built by Cap. Alexander McDougall, these iron vessels resembled floating cigars. The theory behind the design was that waves would roll over the top of the cylindrical hull, and especially when loaded and riding low in the water. A large fleet of these vessels was built between 1888 and 1897. Several of them even saw ocean service. One was built as a passenger vessel, the Christopher Columbus. She was originally built in connection with the Columbian Exposition which was held in Chicago, but went on to serve for many years as a most efficient excursion vessel. In later years whalebacks were converted to a tanker and an automobile carrier. The last of them was finally removed from service as late as the mid nineteen sixties. Although the design proved to have certain limitations, all in all these odd looking vessels proved to be real work horses.

As the twentieth century appeared on the horizon of history, the largest bulk vessels then being built were about 500' long. Only six years later the first 600' vessels appeared. With some continued growth in breadth and depth, these vessels became a basic or standard type for almost thirty years. As time went on, technological improvements in engines, boilers and structural design continued at a steady pace. Larger hatches, improved hatch covers, and shipboard cranes to handle them, contributed to greater efficiency in the loading and unloading of bulk cargoes. The development of new and unusual types of loading and unloading equipment added even more to the efficiency of ore handling. These improvements made Great Lakes bulk vessels among the world's most efficient freight carriers. Electronic vessel navigation equipment was in widespread use on lake vessels while it was still regarded as an unnecessary novelty by most ocean fleet owners and operators.

By the end of World War II, the newest vessels were about 620' in length, although they had swelled to about 70' in breadth or beam. The dimensions of vessels were determined by several factors. One was the limiting dimensions of the locks at several locations on the lakes, plus the parallel limitation of channel depths. The other major factor was the spacing of loading chutes for handling the cargo. With the completion of the present St. Lawrence Seaway in 1959, channels were dredged where necessary to a minimum depth of 27'. The new St. Lawrence locks were built to permit the transit of vessels up to 730' in length, and 75' in breadth. This change in restricting dimensions led to rapid development of a large fleet of new vessels built to take full advantage of the deeper channels and larger locks.

With the completion of the new super-sized Poe Lock at Sault Ste. Marie a short time later, a still newer and larger class of vessel appeared on the scene. These monsters measured 1,000' in length and 105' in breadth. While still limited by the 27' depth of the channels in some ports and restricted areas, this new class of vessel is so much larger, that virtually all former shore side facilities are out dated and unable to serve this class. Over a period of a few years, these vessels gradually stretched out in length until the William J. DeLancey of 1981 which measured 1,013' in length. At the present time there are thirteen vessels of this class. As vessel dimensions increased over recent years, hulls became more boxlike which, in turn, yielded a still greater cargo capacity. Unfortunately, these "super" carriers are so large that they can not pass below Lake Erie because of the limiting dimensions of the Welland Canal. Similarly, these vessels are also restricted to a relatively small number of ports adequate for their needs. Thus, for the most part, these huge carriers sail on a few specific runs over and over again.

Recent years have also seen the lengthening or "jumboizing" of a number of other relatively young vessels to take advantage of presently existing lock capacity at Sault Ste. Marie. All of the "jumbozied" vessels, as well as the new super class vessels, are self-unloaders which, as the name suggests, are not dependant upon shore machinery for the discharge of their cargoes.

As the years have gone by, other types of vessels have come and gone from the lake scene. At the present time, apart from a few remaining ferries and excursion boats, there is no regularly scheduled passenger service on the lakes. At one time there was a large fleet of cruise ships on the lakes, as well as an even larger number of combination passenger - package freight vessels that provided point to point service on regular schedules.

A few specialized rail car ferries still operate on Lake Michigan, although this limited activity is a far cry from the large number of such vessels that were in operation as recently as a generation ago.

Petroleum and chemical tankers have long been a part of the vessel scene on the lakes. But with the expansion of the petroleum pipeline network serving the mid-continent region, the number of tankers formerly engaged in such service has been substantially reduced in the last few years.

Another specialized cargo is that of cement. Most of the vessels in this trade began life as standard bulk carriers. In order to handle cement, hatches and holds have been rebuilt in order to facilitate the use of pneumatic unloading equipment.

The movement of crushed limestone has been a major cargo that has grown with the development of the steel industry. For many years limestone has been moved by self-unloading vessels that run from the quarries to the steel mills, or to rail heads leading to the mills.

Historically, coal has been one of the major lake cargoes. For many years coal served as an upbound cargo that balanced, in part, the flow of iron ore downbound. With the drop in the demand for coal for railroad and heating use, this cargo was significantly reduced. During the past few years, however, the movement of coal has picked up once again. Several Canadian fleets pick up coal at Ohio ports and deliver it by way of the Seaway to the lower St. Lawrence where it is transferred directly into ocean vessels for overseas delivery. Another recent development is the delivery of western coal from the lakehead to shoreside power plants located on the lower lakes and rivers. In recent years coal has moved across the lakes entirely in self-unloading vessels.

But of all of the cargoes moved on the lakes and Seaway today, the movement of grain is next only to iron ore in tonnage. Much of this grain moves downbound in standard bulk carriers of seaway size. Some of it also leaves the lakes in ocean vessels as well. A considerable part of this grain comes from the western provinces of Canada, plus from the mid-west of the United States.

Barges and scows towed or pushed by tugs move numerous cargoes from port to port. With the gradually increasing costs of vessel labor, a considerable amount of experimentation has gone on in recent years in an effort to handle more cargoes by this means. A tug - barge (or barges) can operate with a much smaller crew than a standard lake vessel, thus leading to a considerable saving.

With the opening of the St. Lawrence Seaway in 1959, it became possible for large ocean type vessels to enter the Great Lakes. Thus, today, the lakes play host to hundreds of these "salties" each year. These ships represent many different vessel types, and carry almost any imaginable kind of cargo in and out of the lakes region. Regrettably, this part of the lake shipping industry is being restricted at the present time by extremely high toll charges for the use of the Seaway locks and channels, as well as by the limitation of a short shipping season.

Ocean traffic in and out of the lakes did not begin with the present Seaway. Rather, through traffic from the lakes to the sea began with the opening of the first Welland Canal in 1848. Ocean to lake commerce grew slowly, but with each enlargement of locks and deepening of canals and channels, the volume of tonnage moved upward. The present Seaway makes it possible for much larger ocean vessels to enter and leave the lakes than was previously possible.

The development of vessels on the Great Lakes and their connecting waterways has, over the years, in a very real sense, been a reflection of the state of development of the economies of both Canada and the United States. New vessel types were developed to meet new needs. And these, in turn, were modified or even replaced by the needs of each new day. So it has been in the past, and so it still is today. And if the lessons of the past have any meaning, so it will continue to be in the future.

THE GEOLOGICAL SETTING OF THE GREAT LAKES

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The Great Lakes are some of the largest and most beautiful freshwater bodies in the world. They are also scientifically very interesting, and geologically very young, for they did not even exist during preglacial time, less than a million years ago.

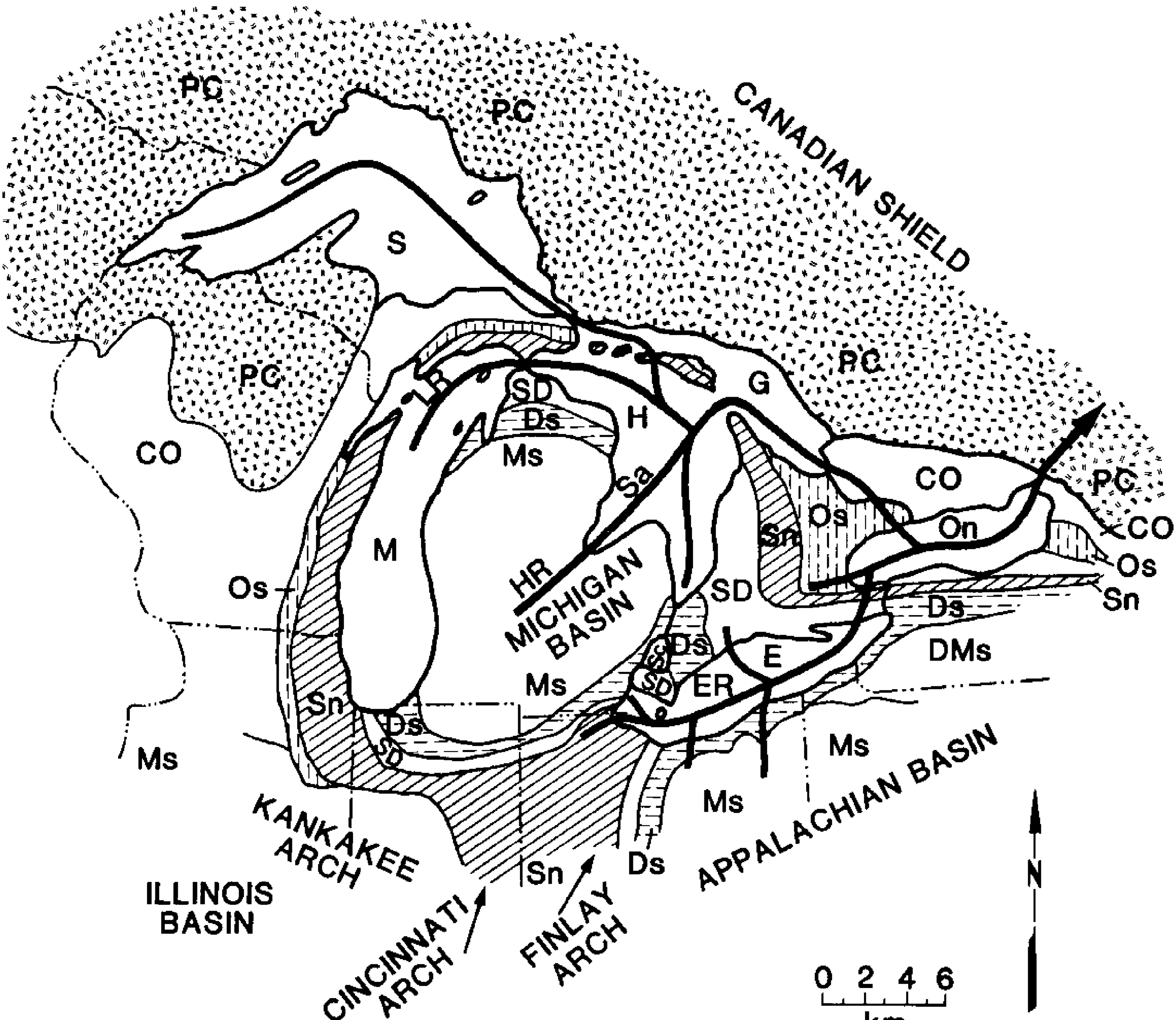
During the many hundreds of millions of years that preceded the Pleistocene Ice Ages, the present locations of the lakes were occupied by rivers, the Laurentian River system, that drained generally toward the northeast, with a tributary in the Lake Erie basin called the Erigan River (see map). These rivers all followed low valleys they had made by eroding deeply down into belts of weak sedimentary rocks (mainly Devonian shales). When the Pleistocene glaciers advanced southward out of Canada, they blocked and destroyed these ancient rivers, and gouged their valleys deeper and wider, thus creating the basins of the modern Great Lakes. The ice cut deepest where it was thickest, farther to the north. As a result, the basins of the northern Great Lakes are especially deep, with their bottoms far below modern sea level, while the southernmost lake, Lake Erie, averages only about 100 feet deep overall, and less than 30 feet deep in its shallow southwestern basin.

The geologic setting of these lake/river basins began far earlier, with the formation of the bedrock in which these basins occur. All of this bedrock is sedimentary rock of Paleozoic age (roughly 200 to 600 million years old), deposited initially as sediments in a shallow intermittent sea. At first, the only sediments were limy precipitates, accumulated very slowly from the clear waters of these seas, lime that was subsequently recrystallized into layers of limestone and dolomite (the magnesium-bearing form of limestone).

About midway through the Paleozoic Era, the nature of the sediments changed. Mud, and later sand, began washing into the sea. The mud represented fine-grained sediments eroded from a rising land mass on the eastern shore of this ocean, and the change from mud to sand reflected the increase in height and steepness of this rising land. As uplift of this land continued, it apparently also raised up adjacent lands, including Ohio and its neighboring states and provinces, allowing the sea waters to drain away, resulting in the deposition of river sands and dead trees, which changed through time into sandstone and coal. The rising land to the east culminated in the formation of towering Himalaya-like mountains, the original Appalachian Mountains (the present Appalachians are just the eroded roots of those ancient high, impressive original mountains!).

Many rivers developed on the slopes of these rising mountains, eroding them. Of these rivers, the main one flowing westward, through this area, was the Teays, which followed a course across West Virginia, Ohio Indiana, and Illinois to join a very small preglacial Mississippi River. Drainage in the form of the Laurentian/Erigan River system also came eastward from some moderately high land to the northwest, creating the lowlands destined to become the basins of the future Great Lakes. Together the erosion of these preglacial rivers formed the modern bedrock landscape of this area.

Map showing generalized distribution of major geologic features related to the geologic setting of the Great Lakes.



Lake symbols:
- S - Lake Superior
- M - Lake Michigan
- H - Lake Huron
- G - Georgian Bay
- Sa- Saginaw Bay
- Sc- Lake St. Clair
- E - Lake Erie
- On- Lake Ontario

Preglacial River symbols:
- LR - Laurentian River
- HR - Huronian River
- ER - Erigan River

Bedrock symbols:
- PC - Pre-Cambrian igneous and metamorphic rocks
- CO - older Cambrian and Ordovician rocks
- Os - weak Upper Ordovician shales
- Sn - resistant, ridge-forming Niagaran Lockport Dolomite
- SD - other Silurian and Devonian rocks
- Ds - weak Devonian shales forming Great Lakes lowlands
- Ms and DMs - resistant plateau-forming Mississippian and upper Devonian sandstones

Special patterns of ridges and lowlands were formed by this erosion, because the sedimentary rocks eroded by these streams were not entirely flat-lying. They had been bent into a series of very shallow, broad structural basins separated by very low, elongate structural rises, or arches (these terms, "basins" and "arches" (anticlines) relate to internal structural patterns of the rock layers and not to landscape features). The main structural basins in this area were Michigan Basin (note diagnostic circular patterns of eroded bedrock in lower Michigan on included map), the (southern) Illinois Basin, and the Appalachian Basin (in southeastern Ohio, western Pennsylvania, and West Virginia). In these areas where the rock layers were bent gently downward, erosion cut much less deeply down through the sequence of Paleozoic rock layers, so that the younger, coal-bearing Pennsylvanian rocks were generally preserved at the surface. In contrast, the low arches (with very gentle slopes on either side, slopes of less than one degree) bent the rock layers upwards,so that erosion could cut deeper into the sequence of rock layers, completely removing the younger layers and exposing the older (Ordovician and Silurian) rocks (see map). The main arch here is the one whose crest extends north-northeastward through Cincinnati, the Cincinnati Arch. In west-central Ohio, this arch divides, forming the northeast-trending Kankakee Arch in northern Indianan and Illinois (see map).

The depth of the erosion accomplished by these streams was affected not only by the location of the rocks relative to these structural basins and arches, but also by the erodability of the rocks themselves. Some of the sedimentary rocks, like sandstone or solid limestone or dolomite, are more resistant to erosion than other rocks and, when erosion takes place, they tend to make ridges or hills. Where weak, nonresistant rocks occur at the surface, on the other hand, lowlands are created, such as the low river valleys that would ultimately become the basins of the Great Lakes.

North of most of the Great Lakes (and all around Lake Superior) is a highland of much older (Pre-Cambrian) igneous and metamorphic rocks. These rocks underlie the younger Paleozoic sedimentary in the south, forming the so-called Pre-Cambrian "basement" rocks there, and rise nearer the surface northwards until they occur at the surface, forming a broad Pre-Cambrian upland not only around the northern Great Lakes but throughout most of Canada (the so-called Canadian Shield). These igneous and metamorphic rocks are the most resistant rocks of all, so the land in the area where these rocks occur is especially high and hilly. Even so, these rocks also have belts of greater and less resistance, so that erosion (first by streams and late by glaciers) has still cut a little deeper along belts of somewhat weaker rock (e.g. the Lake Superior basin).

Most famous of the resistant sedimentary rocks in the lower Great Lakes area is a Silurian dolomite of Niagaran age (about 400 million years old) called the Lockport Dolomite. It is this resistant rock that created Niagara Falls in New York, the line of rocky islands separating Georgian Bay from Lake Huron, an east-west ridge on the Upper Peninsula of Michigan, and the Garden and Door-Green Bay Peninsulas on the west side of Lake Michigan (see map). Other somewhat less resistant rock layers in Ohio form low ridges which extend out into Lake Erie and form belts of islands there, while a much stronger ridge on the very resistant Appalachian sandstones (of Mississippian and late Devonian age) forms the impressive edge of the Appalachian Plateaus southeast of Lakes Erie and Ontario.

Lowlands on either side of the Niagaran Dolomite ridge were created by the erosion of nonresistant sedimentary rocks. Most extensive of these lowlands are those that were occupied by the Laurentian/Erigan river system, lowlands cut generally into weak Devonian shales (see map) and destined to become, following glacial erosion, the basins of the Great Lakes. Lowlands also occur along the outcrops of weak Ordovician shales, lowlands that now contain Georgian Bay, Green Bay, and the bay west of the Garden Peninsula (see map).

With the advance of the earliest of the several Pleistocene glaciers, about a million years ago, the preglacial valleys in the Great Lakes area began to be widened and deepened by glacial erosion, though the deepest erosion was done by the last (Wisconsinan) glacier because of its greater thickness in basins already deepened by earlier advances. The ice also left a complex of glacial deposits, composed of either glacial till or meltwater-deposited gravel, both on the land and on the lake bottoms. Deposits made of glacial till include ground moraine (till spread generally uniformly, making flat land), end moraine (till piled up in a belt of irregular hills along the edge, or end, of the glacier), and drumlins (elongate streamlined hills in localized concentrations down-glacier from lake basins). Gravel deposits include kames (gravel accumulated in holes in the glacier), eskers (narrow winding fillings of ice tunnels), and outwash (flat-topped deposits washed beyond the glacial margin).

As the ice slowly retreated, exposing sections of the Great Lakes basins, many different levels of ice-dammed lakes developed in those basins, the elevations of the lakes being determined by the elevations of their outlets. As the glacial margin alternately retreated and readvanced, exposing or re-covering different potential outlets, the lowest available ice-free outlet for each lake basin varied, resulting in many different lakes levels in each of the Great Lakes basins. More than a dozen different lake levels are recognized in the Erie basin alone (of which the major ones are Lake Maumee at 780′, Lake Whittlesey at 735′, and Lake Warren at 690-675′), and similar complex histories are known for the ice-dammed lakes occurring in the other Great Lakes basins. (There was undoubtedly a similar complex series of ice-dammed lakes following the retreat of each earlier Pleistocene glacier, but no clear record of these many earlier lakes remains.)

Elevations on the beaches of these ice-dammed lakes in Ohio do not change across the state, but wherever these beaches are traced farther north, they rise in elevation. This is because these beaches are tilted upward toward the north, because the land, which had been weighed down by the thicker glacial ice farther north, has risen since the ice melted away. In Ohio, the ice was never thick enough to have affected the land in this way.

As the ice continued to retreat, major changes in lake drainage took place. In the Erie basin, when the glacier finally retreated far enough north to allow the impounded waters to drain eastward, the outflow of lake waters must have been catastrophic, creating a tremendous flood (or possibly floods) eastward across New York and down the Mohawk valley. Similar floods must later have also occurred from ice-dammed lakes in the Lake Ontario basin. The lower end of the Mohawk valley is filled with the kind of thick, coarse, poorly sorted deposits that such floods would generate. Farther north, with continued retreat of the ice, drainage from the upper Great Lakes for a time bypassed Lake Erie entirely, and drained eastward by one or more northern routes.

However, these outlets were short-lived, as isostatic uplift of the deglaciated land to the north allowed the land there to rise, diverting the flow of the upper Great Lakes once more back to the south, by its present route, and the modern Great Lakes were born.

COASTAL PROCESSES (WITH AN EMPHASIS ON SHORE EROSION) ON THE GREAT LAKES

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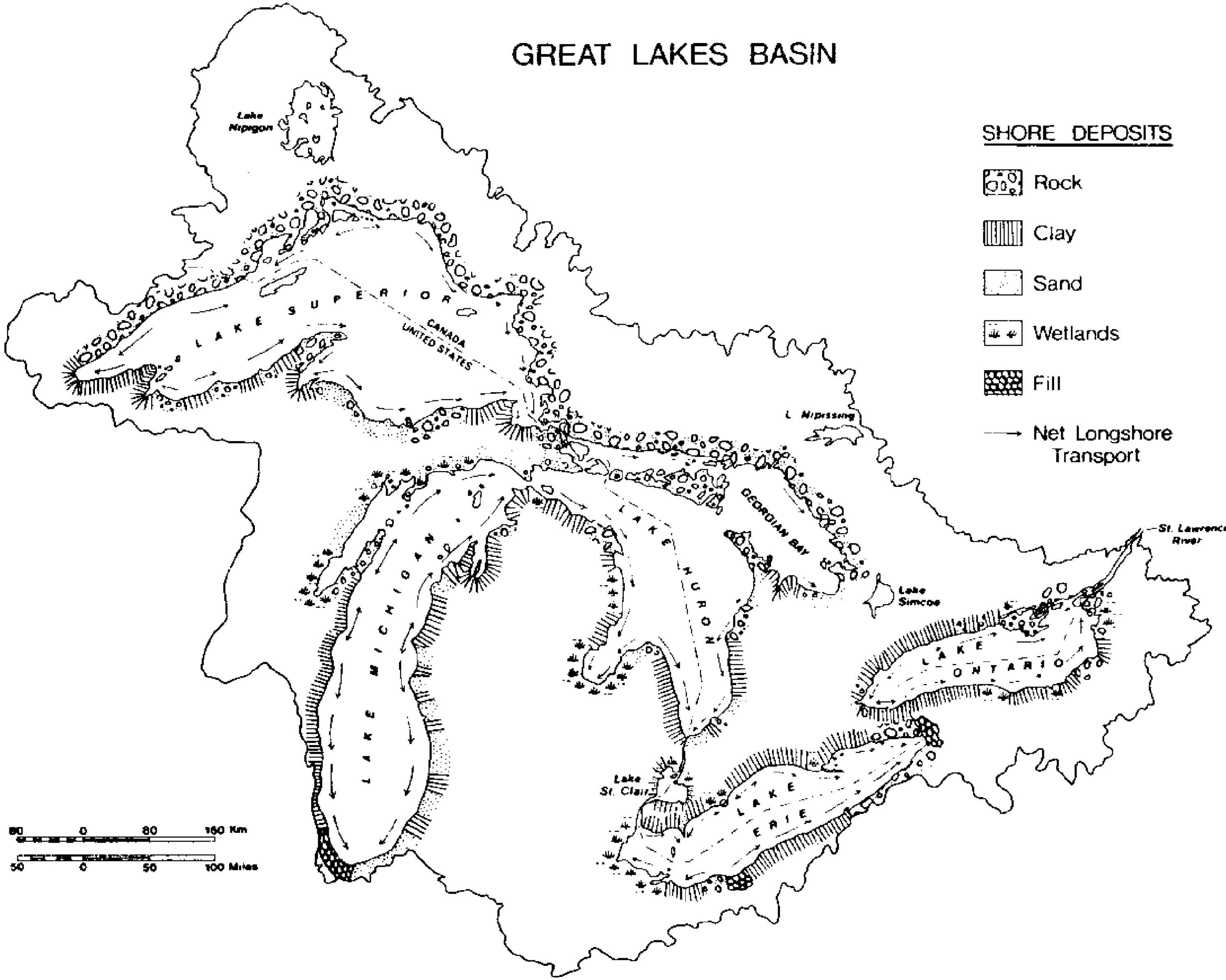
Introduction

The coastal zone, on both the Great Lakes and the oceans, is the dynamic interface between the waves and the land. On the Great Lakes this is the zone that can change from tranquil to turbulent in a matter of hours (if not minutes), and the zone for which major historic changes can be documented. Moreover this is a zone of crucial importance to people in that major issues related to electrical power, commercial navigation, recreation, shoreline development, and the environment have a focus. Almost without exception, the natural physical processes that take place in this zone have a profound effect on these activities and systems.

In this paper I will discuss the overall physical setting (because of the marked effect that the nature of the shore material has on coastal processes) and the physical processes (with an emphasis on shore erosion).

Physical Setting

The lakeshore deposits consist largely of rock, clay, sand, and wetlands (Fig. 1). The rock is exposed along the north shores of Lake Superior and Lake Huron (Georgian Bay and North Channel) and at scattered locations on the other lakes. The rock along Superior and Huron is part of a vast complex of erosion-resistant igneous and metamorphic rocks known as the Canadian shield, whereas the rocks exposed along the lakeshores to the south consist of less-resistant Paleozoic sedimentary rocks. The clay, with intervening stretches of rock, sand, and wetlands, is exposed along most of the remainder of the shore. For the most part it was deposited by or in association with the Pleistocene glaciers and glacier-dammed lakes. The clay is less resistant to erosion than the rock, but more resistant to erosion than the sand, which is related for the most part to glacial and post glacial processes, and which occurs largely along the eastern shore of Lake Michigan. The wetlands occur commonly along Green Bay off Lake Michigan, along Saginaw Bay off Lake Huron, and at the west end of Lake Erie. The wetlands may be associated with narrow strips of sand known as barrier beaches. The relief (the elevation of the shore deposits above the lake) of the lakeshore ranges from essentially zero along the wetland shores to nearly 800 feet along Lake Superior's north shore. The beaches, which are so important as a barrier to wave erosion, are as variable as the relief, and the nature of the shore deposits. For example, wide, sandy beaches characterize the eastern shore of Lake Michigan; narrow, discontinuous beaches characterize the south shore of Lake Erie; and pocket, cobble beaches characterize the north shore of Lake Superior. In general, the nearshore slopes (the submerged surface lakeward of the beaches) are gentle with slopes of no more than a few degrees.



1. The Great Lakes basin including the lakeshore deposits and net longshore transport directions (from the World's Coastline, E. Bird and M. Schwartz, editors, Van Nostrand–Reinhold).

PHYSICAL PROCESSES

Water Levels

Water levels are of singular importance on the Great Lakes for almost all coastal zone processes. However, in contrast to oceanic water levels, the mean annual levels (long term fluctuations) of the lakes show marked fluctuations that have major effects on the coastal zone and on coastal zone interests and environments. Moreover, in contrast to oceanic coasts that commonly experience predictable daily tides of a few feet in amplitude, the long term fluctuations on the Great Lakes take place over a period of a few to several years and are at present unpredictable. Or at least no more predictable than the weather, which is the cause of the fluctuations. In addition to the long term fluctuations are the seasonal fluctuations that have a yearly range of about one foot, and the short term, storm related fluctuations that can raise an area of a lake a few feet in several hours.

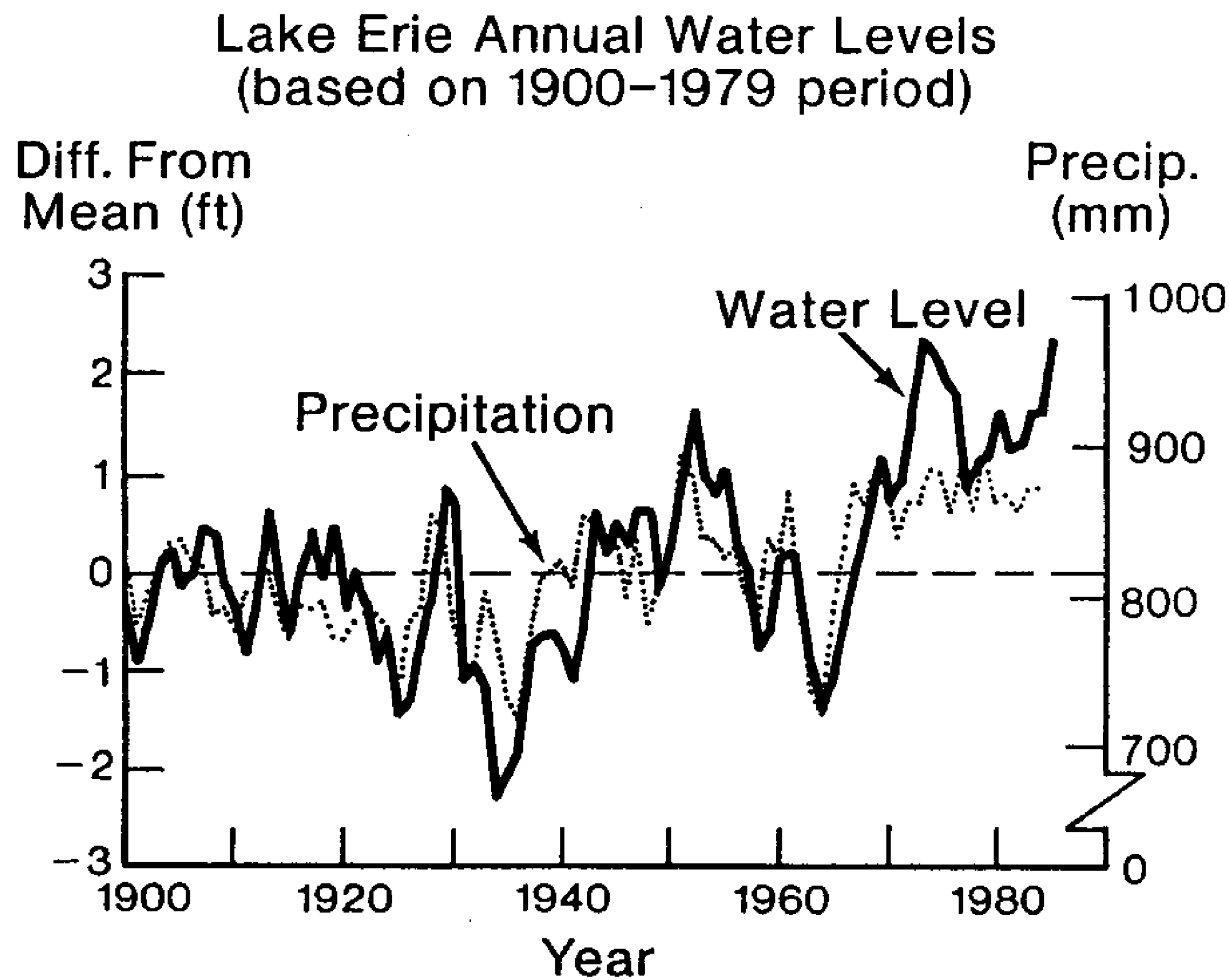
The long term lake level fluctuations can for the most part be tied into the amount of precipitation that falls on the Great Lakes Basin. If there is above normal precipitation the levels of the lakes rise and if there is below normal precipitation the levels of the lakes fall. Evaporation helps accentuate these fluctuations because evaporation rates are generally smaller during periods of above normal precipitation whereas evaporation rates are generally greater during periods of below normal precipitation. The level of Lake Erie is a good example of this with the dramatic fall during the midwestern drought of the mid-1930's, and the gradual, yet persistent, rise in the late 1960's and early 1970's (Fig. 2).

The seasonal fluctuations, which have a range of about one foot, reflect the shorter term variability of the weather. The summer highs reflect above normal precipitation and runoff in the spring and the winter lows reflect below normal precipitation (and greater evaporation) and runoff in the fall (Fig. 3).

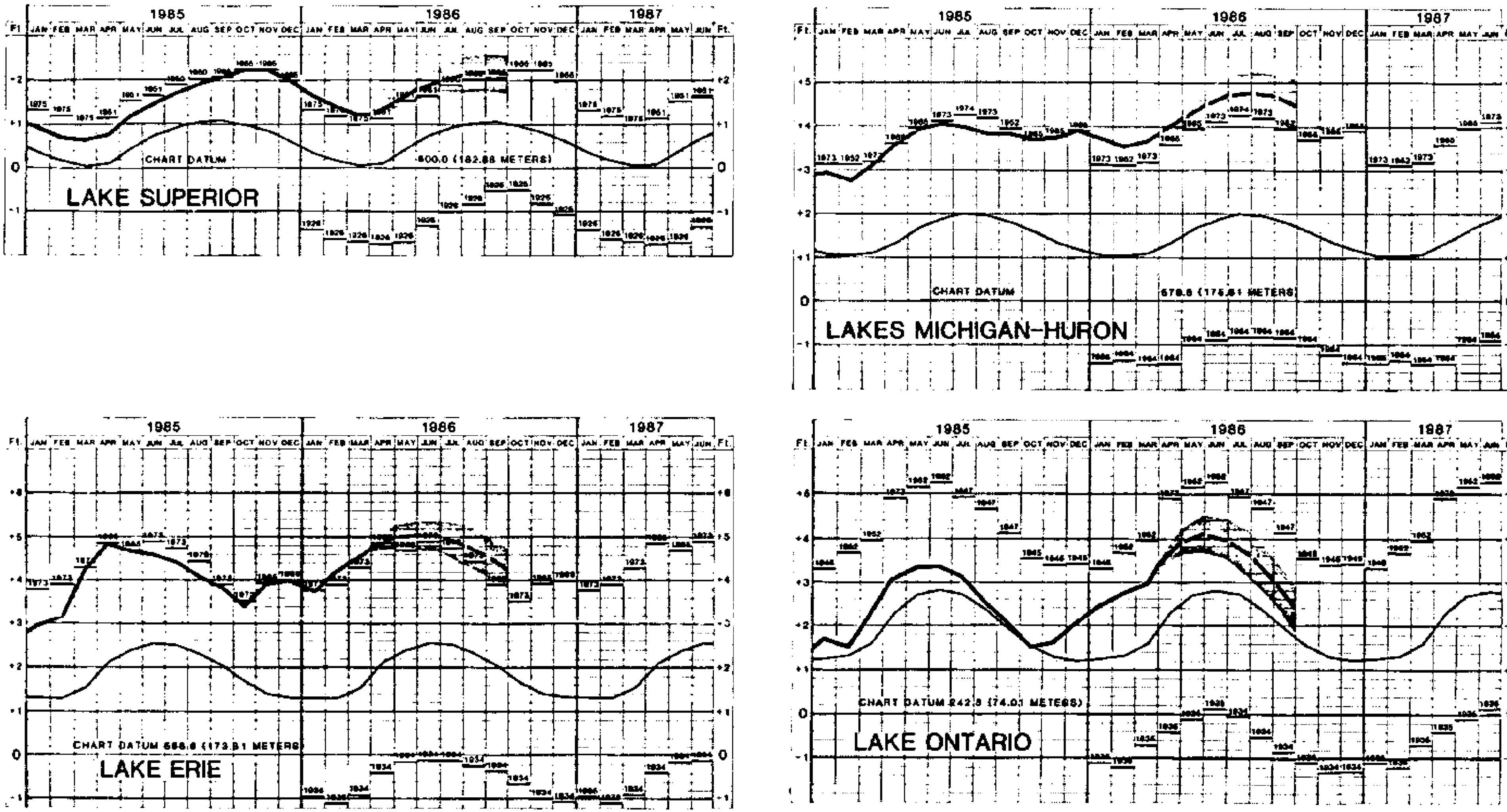
The short term fluctuations are due to storm surges, atmospheric pressure changes ("jumps"), and seiches. The surges are the most significant in terms of coastal processes because of their height, duration, and association with large, wind-driven waves. In essence, wind stress across the lake surface causes mass transport of the lake water; this transport causes a rise in lake level along the lake shore. The lake level rise is eventually compensated by a return flow to the other side of the lake basin that constitutes a seiche, a free oscillation of the lake's surface. Storm surges are much greater on Lake Erie in comparison to the other lakes because of Lake Erie's orientation and shallow depth. A Lake Erie storm surge and subsequent seiche are shown on Figure 4.

Waves and Sediment Transport

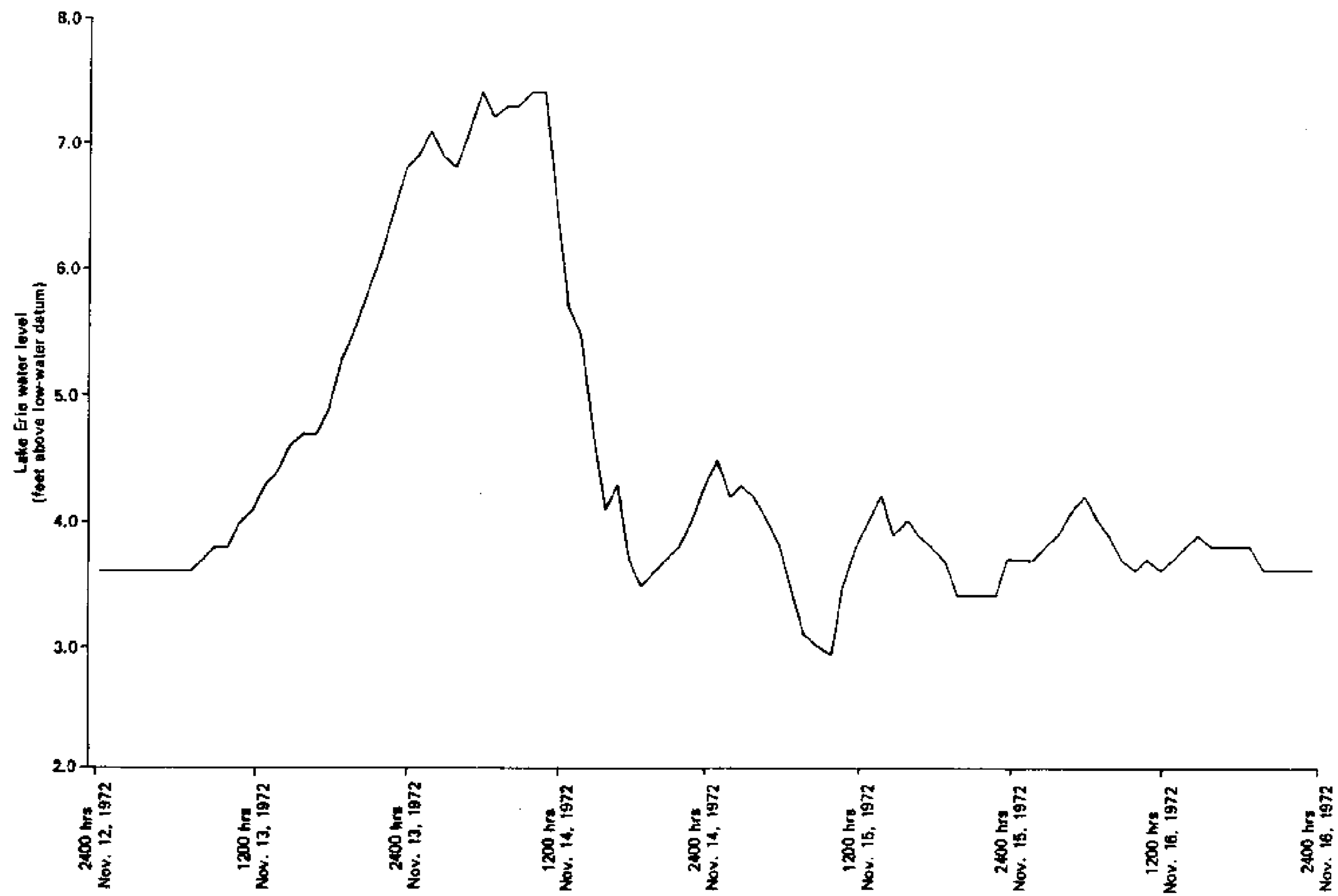
Wind-driven waves-not the swell characteristic of certain ocean coasts-provide the dynamic element to Great Lakes coasts. The winds are generated by both high and low pressure systems traversing the Great Lakes region in a roughly west to east direction. Deep water waves on the lakes have been estimated and hindcast to reach about 20 feet in height, however, once these waves reach the shallow coastal slopes their energy is lost to friction and breaking, and for the most part the storm waves that reach the shore are no



2. Comparison of Lake Erie water levels and precipitation (from F. Quinn, Great Lakes Environmental Research Laboratory, NOAA).



3. Long term (1900–1985) average lake level curve by month, and maximum monthly high and low lake levels. (U.S. Army Corps of Engineers, Detroit District).



4. Lake Erie storm surge and subsequent seiche from the 13–14 November 1972 storm, recorded at Toledo, Ohio (from C. Carter, Ohio Geological Survey Info. Circular 39).

more than three to six feet in height. Fortunately for the people that live along the shore most of the Great Lakes wind storms occur from the late fall to the early spring when lake levels are lowest and when lake and/or shore fast ice are present to restrict the formation of waves or keep the waves from reaching the shore (Fig. 5).

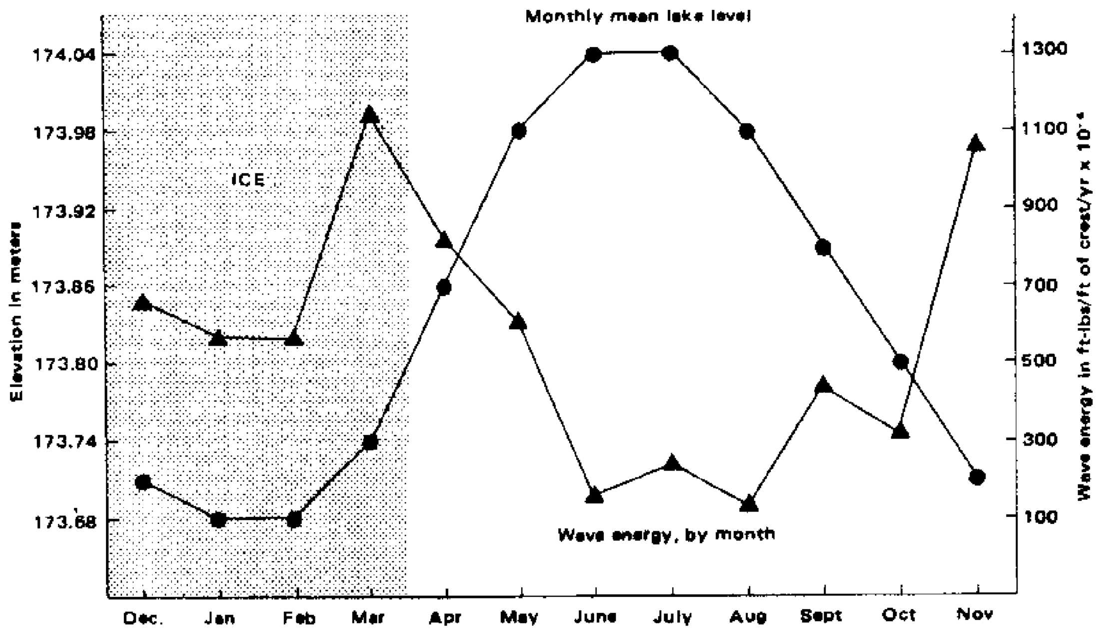
The waves, aside from shore erosion, transport appreciable quantities of sand along the shore. Sand accumulation measurements made at harbor jetties indicate up to 100,000 cubic yards of sand per year can be transported and deposited adjacent to harbor structures on the Great Lakes. Naturally the sand is not in continual motion because winds are not constantly blowing onshore nor is the sand moved in just one direction because the winds blow onshore from different directions. For example, on Lake Erie, even at exposed locations such as Cleveland, and Erie, Pennsylvania, the lake surface is characterized by calm conditions or by waves less than a half a foot in height about 80% of the time. Nonetheless, there is usually a preferred (net) direction toward which sand is episodically moved. Furthermore, because of the importance of sand as a buffer between lake waves and the land, and as a recreational resource a knowledge of the direction and quantity of sand transport ("longshore drift") is significant.

Shore Erosion

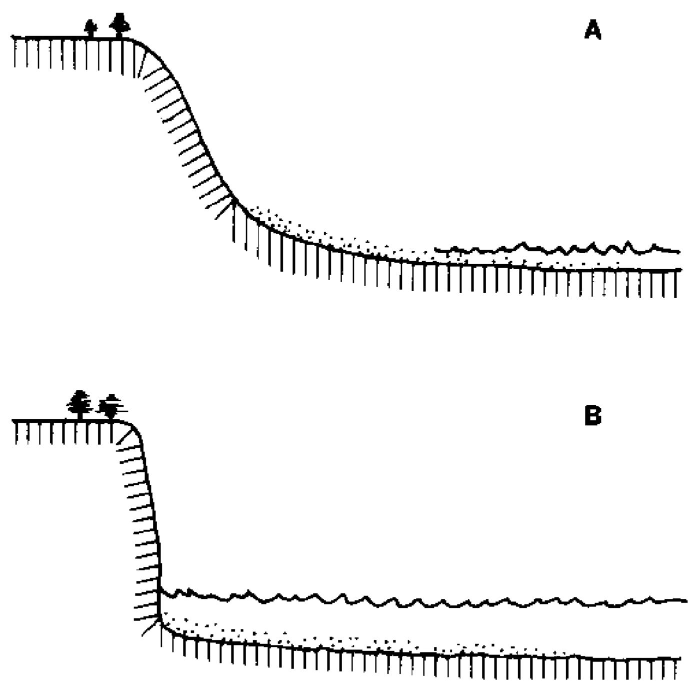
The waves that reach the shore erode the shore. The higher the lake, the closer waves break to the shore (because of deeper water), and the greater the amount of wave energy that reaches the shore (Fig. 6). Naturally, the greater the wave energy reaching the shore, the greater the shore erosion.

Waves erode the shore in different ways. They erode the shore by the force created by impact, by the force created by the compression of air and/or water into cavities and fractures, and by simply abrading (sand blasting) the shore with sand picked up by the waves on the beach. For a given lakeshore setting the nature of the shore material has a major effect on the erosion rate. For example, erosion rates are usually less than 1 foot/year for rock, 2-3 feet/year for clay, and higher but quite variable for sand. The rates are nonlinear and are closely tied into lake level. For example, at a low lake level there may be little if any shore erosion because the storm waves break far offshore and whatever wave energy reaches the beach is easily damped before it reaches the shore. On the other hand, at a high lake level even small waves can reach a shore with a narrow (probably submerged) beach (Fig. 7). At high lake levels erosion rates can be several times the long term rate; in fact, there may well be a threshold level at which time erosion will take place practically everywhere along a lakeshore if there is insufficient beach width to protect the shore from waves.

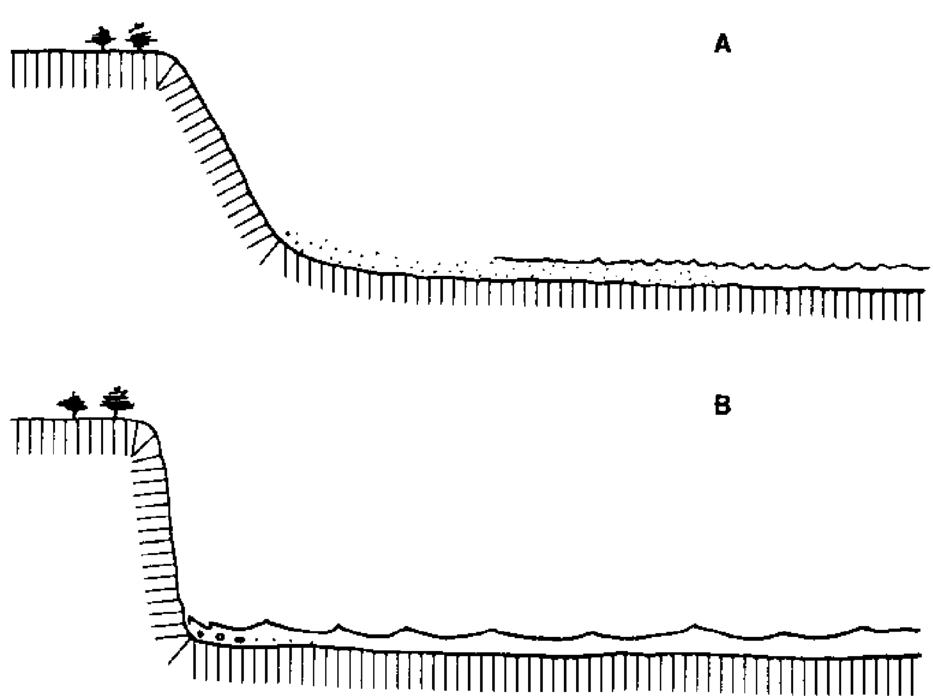
The toe of the lakeshore slope or bluff is crucial to the erosion process. The crucial nature of this area in the wave erosion zone can be illustrated in terms of an erosion cycle that is applicable to the Great Lakes shores with the exception of the shore made up of barrier islands and wetlands (Fig. 8). The cycle can take place in a year or may take place over a period of several years. The principle is this: (1) during a high lake level waves erode the toe of the slope creating an unstable slope (this process may take place over a few weeks); (2) slope failure (mass wasting) takes place in the form of rock/clay falls, slumps, slides, or debris flows, and (3) subsequent erosion (usually at



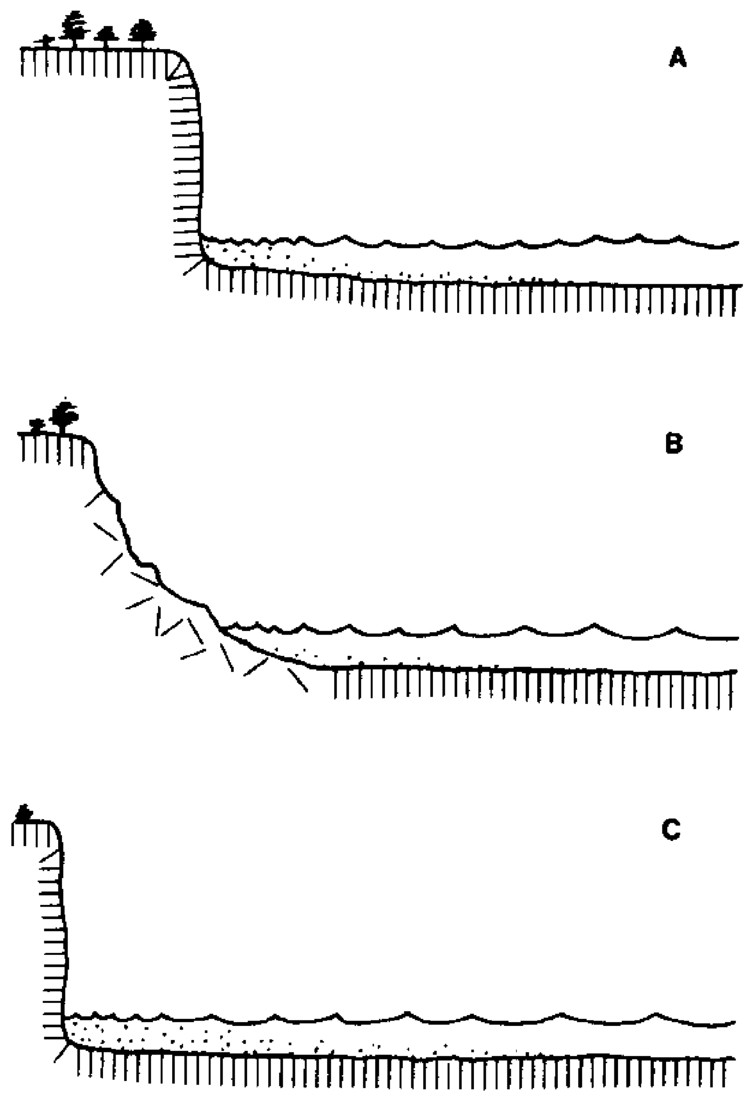
5. Wave energy, lake level, and ice on Lake Erie (from C. Carter, D. Guy, Jr., and J. Fuller, GSA Cincinnati '81 Field Trip Guidebooks, v.3).



6. The effect of lake level on wave erosion. Wave energy lost to beach at a low lake level (A), and wave energy expended on the shore at a high lake level (B).



7. The effect of a beach on wave erosion. Wave energy is lost to the wide beach that protects the shore (A) whereas at the same lake level, wave energy reaches the shore because of the lack of a wide beach (B).

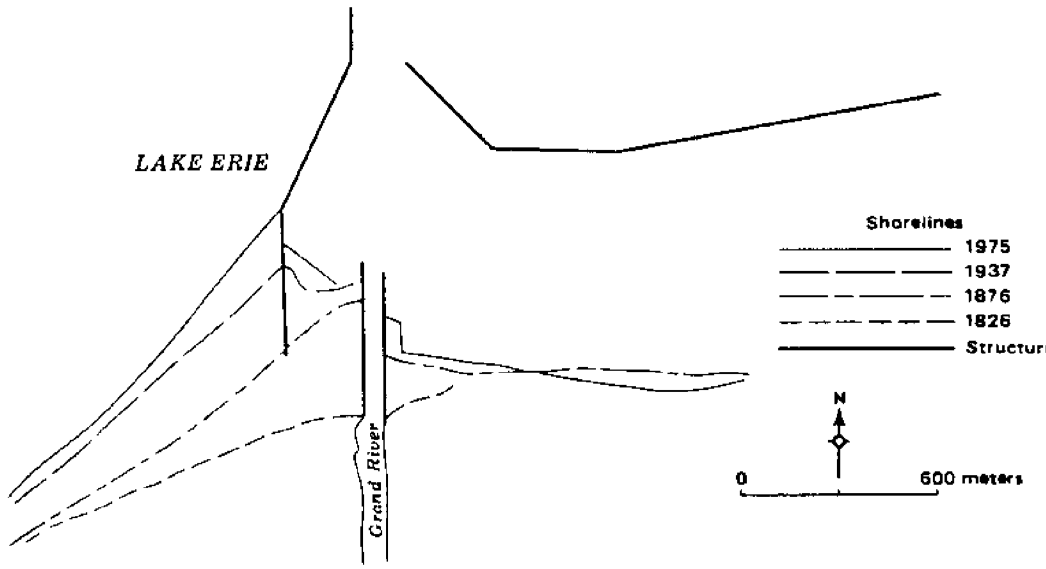


8. The Erosional Cycle.
   (A) Erosion at the slope toe during high lake level.
   (B) Slope failure.
   (C) Erosion of the debris deposited by the slope failure and renewed erosion at the slope toe.

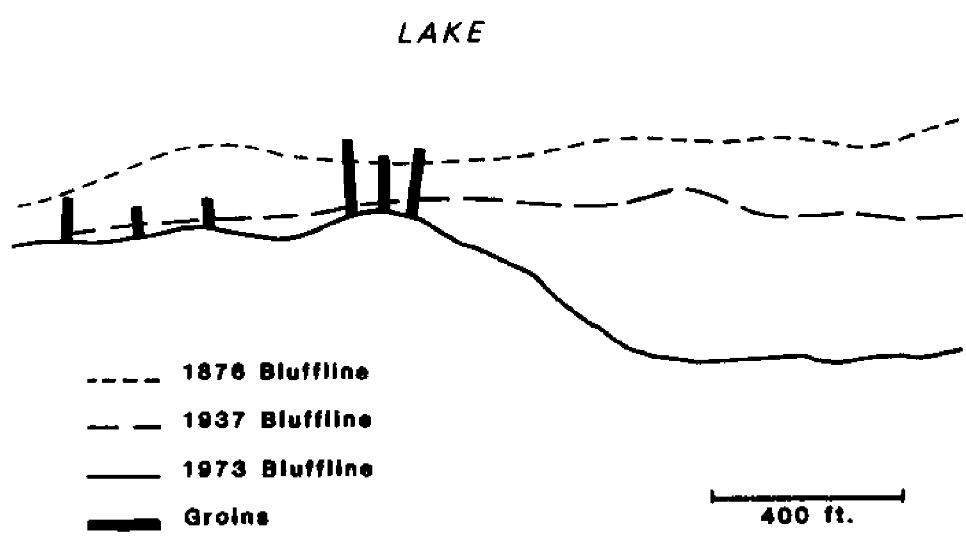
a high lake level), of the toe of the slopes allows the waves once again to create another unstable slope. The erosion cycle illustrates the significance of lake level (or on the oceanic coasts, sea level) to shore erosion. For if the mass wasted debris at the toe of the slope were allowed to accumulate, the slope would eventually reach a stable angle of repose with downslope movement then restricted to the relatively slow slope process of creep. However, if there is wave erosion of the mass wasted debris as there is along much of the Great Lake shores, the slope never reaches equilibrium and erosion persists. In human terms the overall shore erosion problem is harder to comprehend because of the long term fluctuations in lake level. For example, a person may buy a house along the lakeshore at a low lake level, i.e. at a time when there is a relatively wide beach and when mass wasted debris commonly covered by vegetation has accumulated at the toe of the slope giving a semblance of stability. But with the return of a high lake level, the beach is partially (if not wholly) submerged and waves then erode the mass wasted debris to the surprise of the shoreland owner. Eventually the mass wasted debris is removed and erosion of the "in-place" shore continues the cycle.

People, as they have done in so many other natural systems, have had a major impact on shore processes, particularly shore erosion. Human effects on erosion along the Great Lakes shore can be looked at in two ways: the effect of the harbor structures, and the effect of the shore protection structures. The harbor structures that have had the most effect are the jetties that were built to keep the river mouth harbors free of sediment. These structures block and/or divert the longshore transport of sand and in so doing usually deprive the downdrift beach of sand. Naturally, this leads to a wider beach (and thus more protected shore) along the updrift shore, but a narrower beach (and thus a less protected shore) along the downdrift shore. Unfortunately the length of shore affected by the loss of sand is generally several times the length of the shore affected by the gain of sand. The Fairport Harbor area (Grand River) along the south shore of Lake Erie is an excellent example of the effect of the harbor structures. The jetties that were first constructed in the mid-1820's, and subsequently lengthened, have trapped appreciable quantities of sand from the net west to east longshore transport system. This has resulted in a build-up of sand into the lake adjacent to the west jetties of more than 2000 feet and shore protection in the form of a wide beach for about one mile to the west (Fig. 9). On the other hand, there has been a tremendous loss of sand in the beaches at least for 4 miles to the east of the jetties that has led to accelerated erosion along this shore (Fig. 10). Naturally if the setting and processes are different, the effects will be different, but overall the jetties have had a major effect on sand transport and thus on the distribution of sand along the Great Lakes shores. And, almost without saying, a major effect on erosion rates.

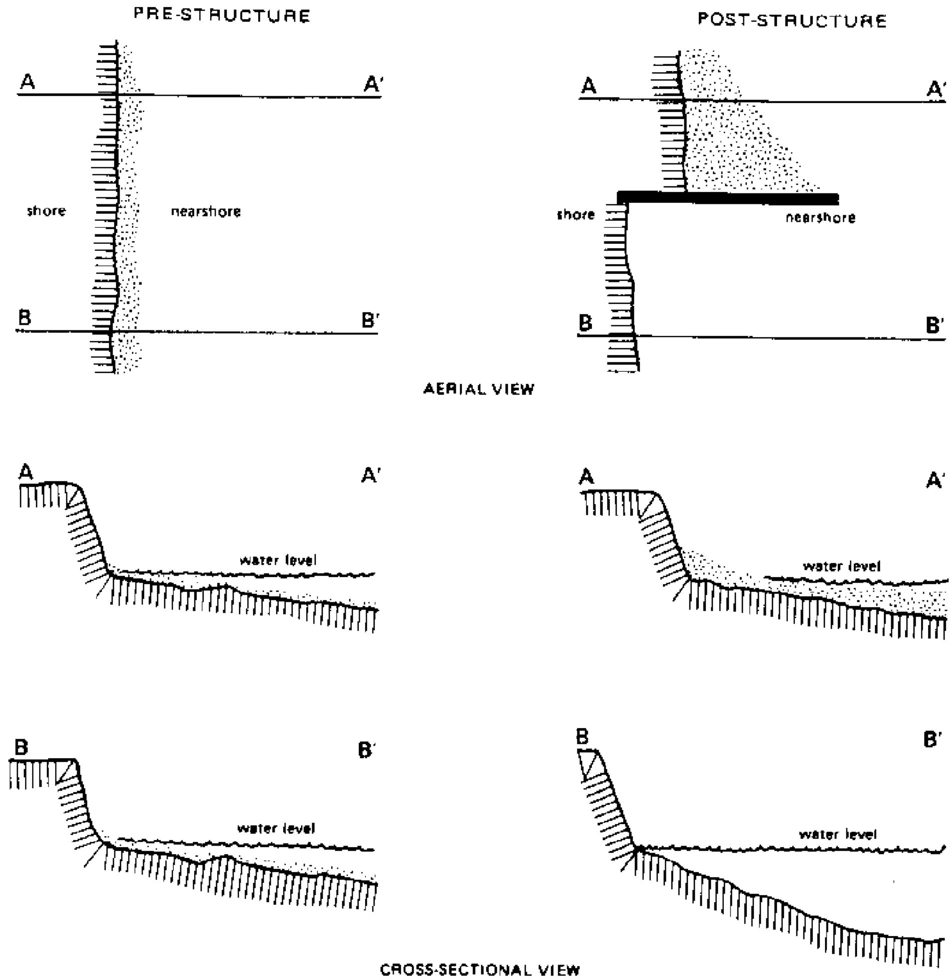
The shore protection structures that have had the most effect are the groins, and the seawalls. Groins act as small jetties in that they block and/or divert the longshore transport of sand and in so doing lead to the formation of a wider beach on one side of the structure, which is the basic purpose of a groin, but again, a narrower beach on the other side of the structure (Fig. 11). Therefore, there are the small structures (groins) affecting the longshore transport of sand in much the same way as the similar large structures (jetties). Moreover, the apparent necessity for the construction of the groins has been created in many instances by the jetties that have contributed to narrower beaches and thus the need for shore protection.



9. The Fairport Harbor (Grand River) area with shorelines and harbor structures (from C. Carter, D. Guy, Jr, and J. Fuller, GSA Cincinnati '81 Field Trip Guidebooks, v. 3).



10. Accelerated erosion at Painesville-on-the-Lake east of the Fairport Harbor jetties. Local erosion caused by groins is greatly amplified by sand trapped at Fairport Harbor.



11. Changes caused by a groin (from C. Carter and D. Guy, Jr., Ohio Geological Survey Rpt. Inv. 115).

12. Changes caused by a seawall.

Seawalls, on the other hand, armor the shore and thus make it more resistant to wave attack. However, erosion takes place at the base of the structures by the downward deflection of wave energy. This leads to greater energy reaching the shore (deeper water) as well as accelerated sand transport along the shore (Fig. 12). And, probably more importantly, because the shore is the principal source of the beach sand, the seawalls by armoring the shore and reducing erosion rates, reduce the amount of sand entering the system. This leads to narrower beaches and consequently higher erosion rates. Moreover, with both groins and seawalls the distribution of sand along the shore is becoming increasingly nonuniform and with larger numbers of structures the distribution will become even more sporadic.

What about the future of the Great Lakes coastal zones in terms of human development? The stretches fronted mostly by manmade shore protection structures will lose their beaches as a diminished sand supply coupled with accelerated longshore sand transport will erode sand from the beaches. On the other hand, the stretches that lack manmade structures will continue to have beaches as shore erosion will provide sand to replenish the sand moved along the shore by longshore currents. However, if manmade structures are built along the shore there will be less sand entering the system from erosion and the beaches will narrow.

REBIRTH OF LAKE ERIE:
Recovering from Phosphorus Enrichment

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The Ohio State University

Lake Erie, as one of the Great Lakes of North America, represents a significant source of freshwater for the people of the United States and Canada. Lake Erie is the shallowest and southernmost, and even prior to settlement it was furthest along in the natural process of eutrophication. In the early 1800s human activities began accelerating this process, until by the middle of this century the lake had aged alarmingly. The early settlers drained the vast coastal wetlands and stripped away the natural protective cover from the rich uplands. Lake Erie's tributaries then carried high amounts of sediment to the lake, silting over fish spawning reefs in the shallow western basin. Industry then followed agriculture along the banks of the lakes' main tributaries: Detroit, Maumee, and Cuyahoga Rivers giving rise to the large cities of Detroit, Toledo, Cleveland, and Buffalo. Industry and increased populations, along with the use of artificial fertilizers on farm lands, brought nutrients, primarily nitrate and phosphates, that hurried the lake's aging process.

The nitrate and phosphate pollution fed the algae, causing blooms of blue-green slime that blanketed most of the western basin and large reaches of the central basin's south shore in the early 1960s. As the algae spread, it consumed the bottom oxygen needed to support other forms of aquatic life. By 1970, large portions of the central basin's hypolimnion were anoxic, being totally depleted of oxygen in the late summer months. At this time many of the swimming beaches along the lake were closed because of high coliform counts from sewage discharges, or were not used because of objectionable algal debris.

During the latter 1960s, remedial actions were planned and by the late 1970s, many of these plans were at least partially implemented. In the early 1980s the first signs of lake recovery were observed. Today, the area of summer anoxia is reduced significantly from that of the early 1970s, the concentration of dissolved solids is down to 1950s values, and production of prized fish species (such as walleye) is at a record high.

Phosphorus in Lake Erie

Cultural eutrophication of Lake Erie is being combated by programs to decrease phosphorus loading from all sources. This is the principal focus of lake restoration efforts. Remedial programs for reducing phosphorus loadings from municipal wastewater treatment plants (MWTP) in the Lake Erie Basin have resulted in a substantial decrease in phosphorus loading to the lake. Since 1982, the average loading objective of 1.0 mg/l for all major MWTP has been met, but several individual MWTP exceed the target value. It should be noted that the average loading objective of 1.0 mg/l applies to major wastewater treatment plants only (i.e., those plants discharging one million gallons per day or more). For example, the flow-weighted average phosphorus concentration of minor wastewater treatment plants in Ohio is still approximately 4.0 mg/l.

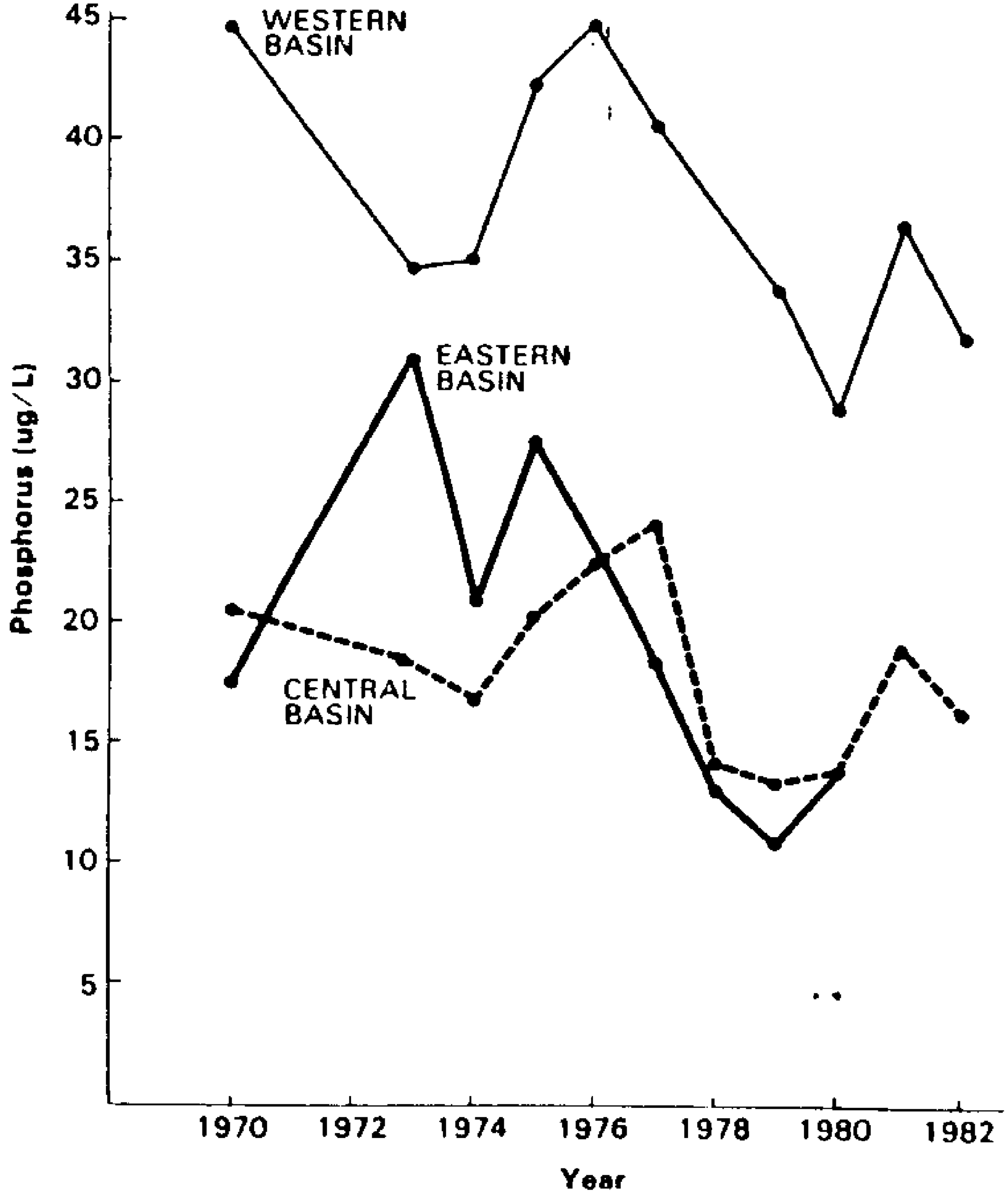
The 1978 Great Lakes Water Quality Agreement between Canada and the United States contains the basic requirement to reduce the phosphorus concentrations in municipal discharges to 1.0 mg/l in all the Great Lakes Basin. It also calls for other programs or additional requirements needed to reduce point and nonpoint sources in order to achieve target loads of 11,000 metric tonnes/year for Lake Erie (a reduction to this level is expected to eliminate anoxic conditions in the central basin hypolimnion). However, if all municipal treatment plants in the Lake Erie Basin were discharging phosphorus at 1.0 mg/l, the total phosphorus load to the lake would still be 13,000 tonnes/year. Thus, in order to achieve the target load of 11,000 tonnes/year a further reduction of 2,000 tonnes/year from other sources is required.

Total phosphorus loading to Lake Erie from all external sources has declined from a peak of 28,000 tonnes in 1968 to 12,400 tonnes in 1982. This represents a 56% decline over the 15-year period. The Detroit River, which supplies about 90% of the inflowing water to Lake Erie, has shown a remarkable improvement; phosphorus loadings decreased 60% from 1971 to 1980, primarily as a result of improvements to the Detroit wastewater treatment plant.

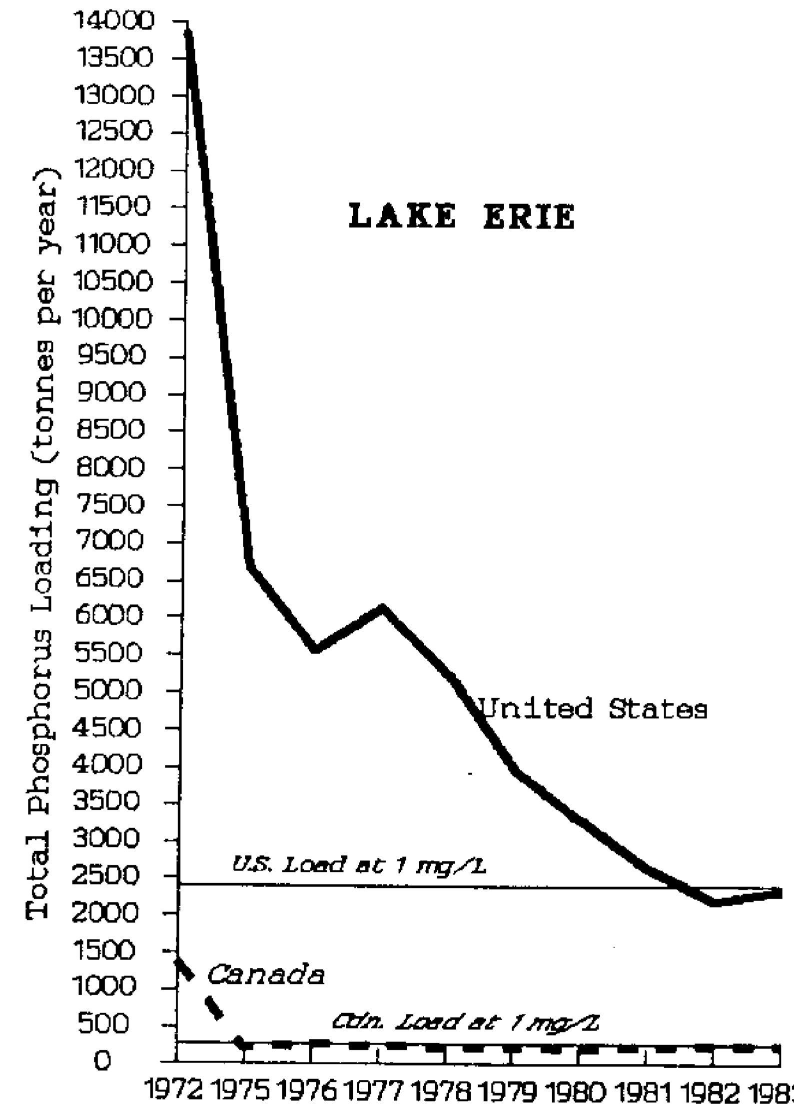
In the early 1970s, the concentration of phosphorus in influent wastewater to municipal treatment plants averaged about 10 mg/l within the Lake Erie drainage basin and the mean effluent concentration was approximately 7 mg/l. By 1980, many plants had installed phosphorus removal systems which resulted in an average effluent concentration of 1.6 mg/l for all Ohio plants and concentrations as low as 0.6 mg/l for the Detroit sewage treatment plant in 1982. Likewise, municipal loading of phosphorus to Lake Erie has declined from over 15,000 tonnes in 1972 to about 2500 tonnes in 1983, a reduction of over 83%.

In 1972, the volume-weighted average phosphorus concentrations of wastewater treatment plant effluent to Lake Erie was about 5.7 mg/l. By 1982, this had fallen to slightly below the target concentration of 1.0 mg/l. However, the International Joint Commission (IJC) recommends that special efforts be initiated to ensure that the 6 Lake Erie treatment plants which have not achieved the target are brought into compliance.

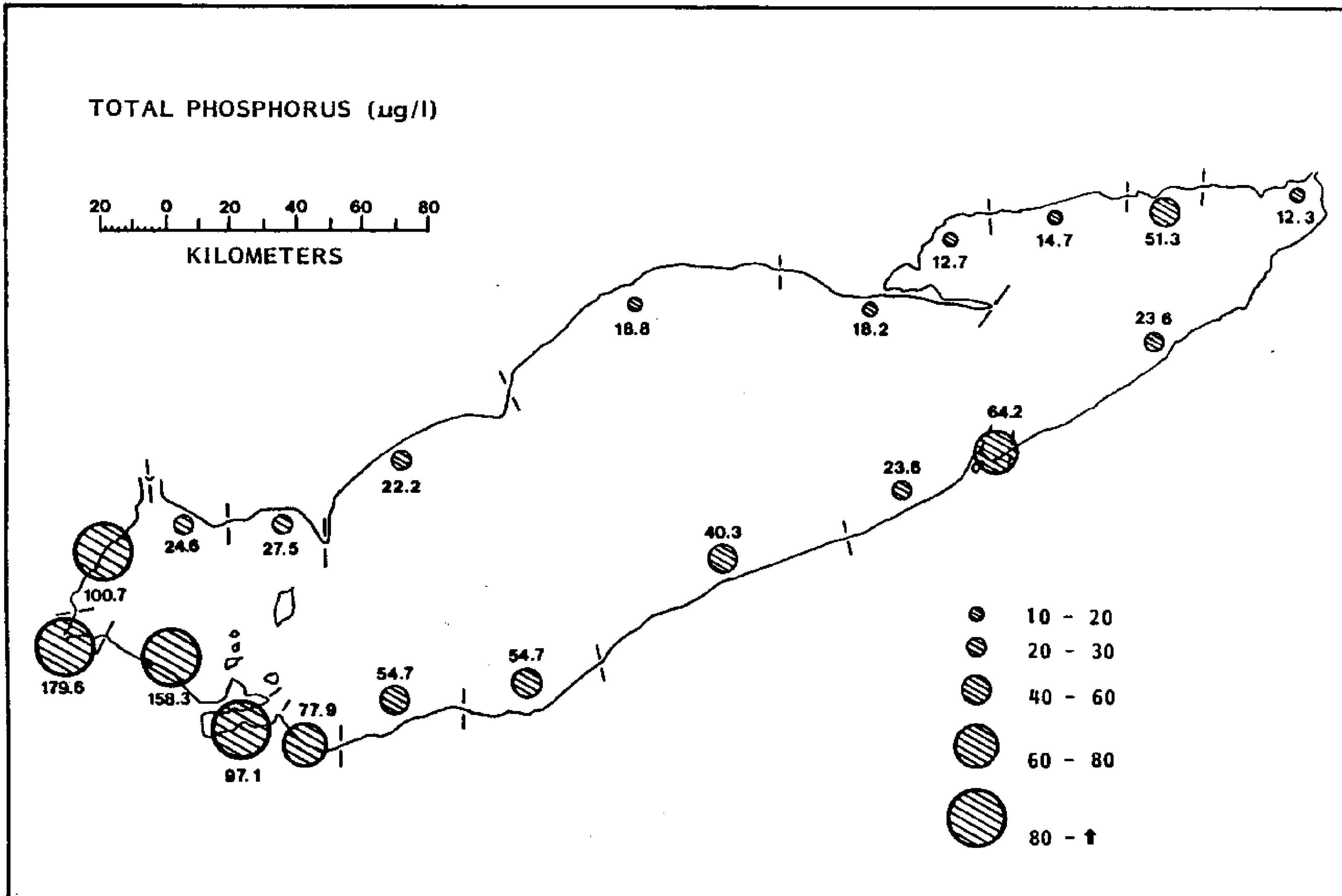
TOTAL PHOSPHORUS LEVELS IN LAKE ERIE



MUNICIPAL PHOSPHORUS LOADINGS



MEAN NEARSHORE CONCENTRATIONS OF TOTAL PHOSPHORUS (1978-1979)



In 1981, about half of the 40 major wastewater treatment plants in the Great Lakes Basin did not meet phosphorus effluent requirements of 1.0 mg/l. By 1984, only 25% exceeded the limit. Unfortunately, 6 of 10 violators are in the Lake Erie Basin: (1) Wyandotte, MI, (2) Toledo, OH, (3) Akron, OH, (4) Cleveland Westerly, OH, (5) Euclid, OH, and (6) Erie, PA.

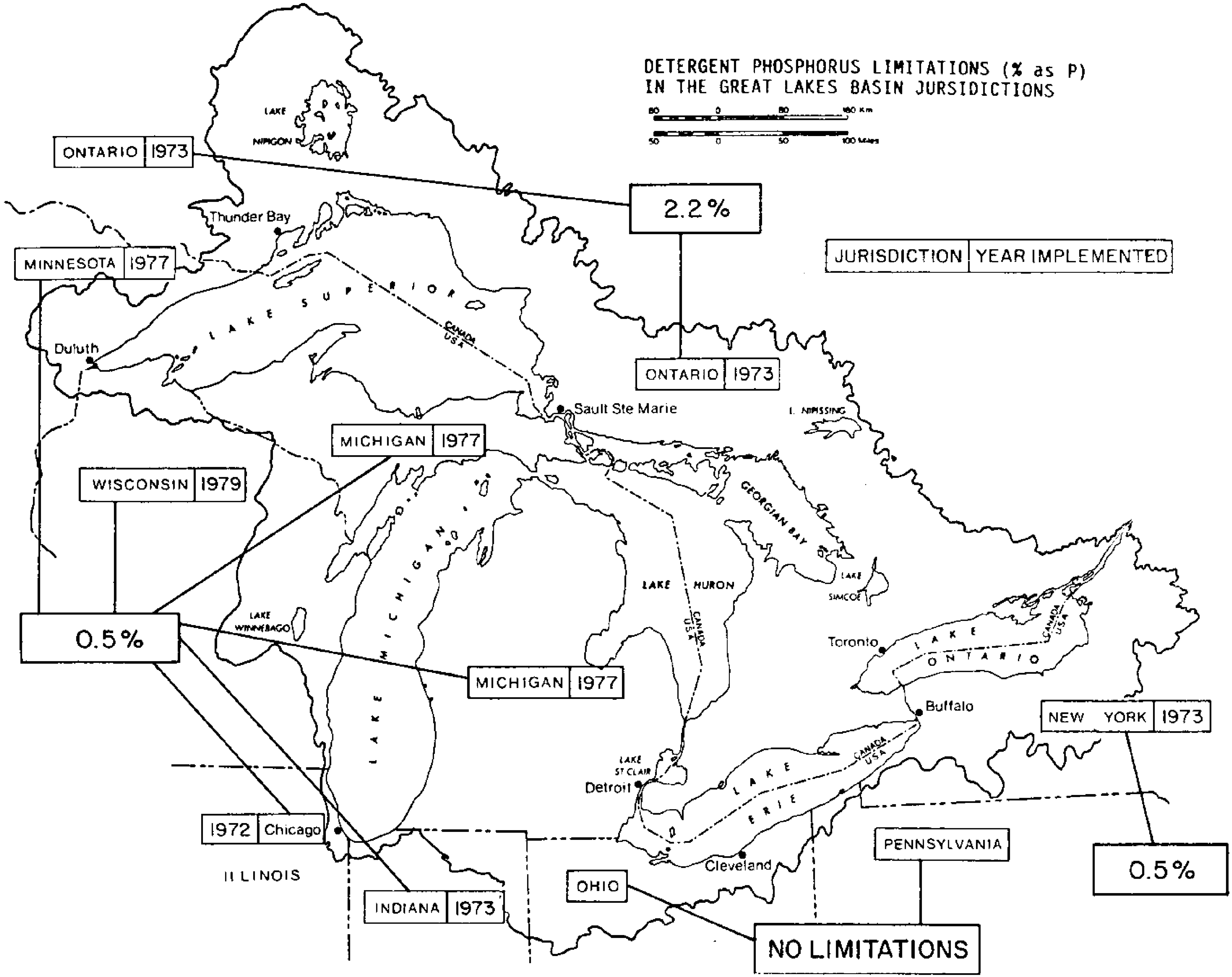
Phosphorus concentrations in the open waters of Lake Erie are highly variable and have not decreased in a fashion comparable to reductions in phosphorus loadings, except along the north shore of the western basin. Here, in response to reduced loadings from the Detroit River, concentration of phosphorus in Ontario waters decreased approximately 40% in the ten-year period from 1970 to 1979. Similarly, in the 15-year period from 1968 to 1982, the annual mean phosphorus concentrations in the central basin epilimnion have fallen from 21.3 to 12.0 ug/l (44% decline). Elsewhere phosphorus released from sediments through wave resuspension and anoxic regeneration keep levels high.

All of the Great Lakes jurisdictions, with the exception of Ohio and Pennsylvania, have enacted legislation to control the amount of phosphorus permitted in household detergents. The IJC recommends that these states consider the implementation of detergent phosphorus limitations as a component of their phosphorus management strategies for the Great Lakes.

Agricultural cropland phosphorus is estimated to account for 65% of the phosphorus entering Lake Erie. To achieve the target loading of 11,000 tonnes/year, Ohio's portion of the goal is a reduction of 1,385 tonnes, of which about 900 tonnes is assigned to cropland phosphorus reduction. Many agencies are currently involved in programs that are attempting to reduce loads through comprehensive land treatment, residue management, fertilizer management and livestock waste management. Although these programs are resulting in steady increases in conservation tillage acreage and increased knowledge of fertilizer management, they will not be enough to meet the target load reduction. Current estimates indicate that conservation tillage increases will result in a phosphorus reduction of 71 tonnes by 1988. Existing erosion and animal waste control programs (other than cropland management) will reduce phosphorus loads by another 120 tonnes. Because only 14% of the goal can be achieved using existing erosion control and water quality protection programs, the vast majority of the reduction must be met with new programs and funding. The Ohio Environmental Protection Agency estimates that nearly 2,000,000 acres of cropland must utilize conservation tillage to meet the phosphorus goal.

Dissolved Substances in Lake Erie

Dissolved solids records for the period 1900 to 1960 in nearshore waters of central Lake Erie show dramatic increases in conductivity, chloride, calcium, sulfate, and sodium plus



DETERGENT PHOSPHORUS LIMITATIONS (% as P)
IN THE GREAT LAKES BASIN JURSIDICTIONS
JURISDICTION | YEAR IMPLEMENTED
ONTARIO 1973
2.2%
ONTARIO 1973
MINNESOTA 1977
WISCONSIN 1979
MICHIGAN 1977
MICHIGAN 1977
0.5%
1972 Chicago
ILLINOIS
INDIANA 1973
OHIO
PENNSYLVANIA
NO LIMITATIONS
NEW YORK 1973
0.5%
LAKE NIPIGON
Thunder Bay
Duluth
LAKE SUPERIOR
Sault Ste Marie
L. NIPISSING
GEORGIAN BAY
LAKE SIMCOE
LAKE HURON
LAKE MICHIGAN
LAKE WINNEBAGO
LAKE ST CLAIR
Detroit
Toronto
LAKE ONTARIO
Buffalo
LAKE ERIE
Cleveland
CANADA
USA

potassium. From 1966 to 1980 conductivity values indicate a decline in the total amount of dissolved substances in central Lake Erie, falling approximately 8% during this period. Chloride shows a more dramatic improvement, dropping about 26% from a concentration of 25.0 mg/l in 1966 to 18.4 mg/l in 1979. Much of this decline can be attributed to elimination of waste brine pollution from the Grand River near Painesville, Ohio, in the early 1970s. In the eastern basin, Presque Isle Bay at Erie, Pennsylvania, has experienced a marked decrease in alkalinity (largely bicarbonate ions), falling from 96 ppm in 1945 to 87 ppm in 1978. Other conservative ions (e.g. calcium, sodium, and sulfate) have ceased to increase in the lake and have remained relatively stable over the past decade.

Nitrogen is the only major dissolved constituent in the waters of Lake Erie which has shown a dramatic increase in the past decade. Increased use of chemical fertilizers and gaseous emissions of nitrogen compounds within the lake's drainage basin are major causes. Combined nitrate and nitrite loading from the Detroit River more than doubled in the period 1967 to 1979.

Dissolved Oxygen in Lake Erie

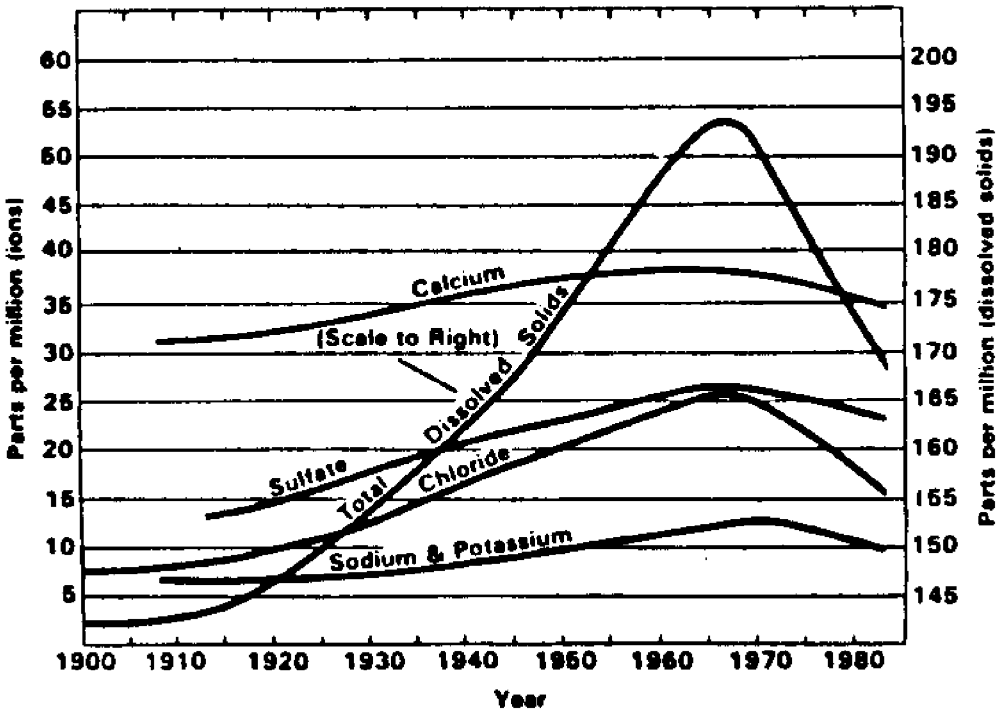
The central basin hypolimnion has suffered seasonal anoxic conditions for at least 40 years. Taking into account natural variability in oxygen depletion rates due to meteorological factors, the highest oxygen depletion rates occurred during the 1960s and 1970s when Lake Erie was at the height of cultural eutrophication, exhibiting the highest phosphorus concentrations and algal biomass. From 1980 through 1984 oxygen depletion rates have decreased and are less variable.

In the central basin of Lake Erie, the rate of hypolimnetic oxygen depletion more than doubled between 1930 and the mid-1970s. In 1930, the volumetric rate has been estimated at 0.05 mg/l/day, while in 1974 it was measured at 0.13 mg/l/day. During the same period the area of the basin subjected to anoxic conditions rose from 300 km^2 in 1930 to 10,250 km^2 in 1974. Studies conducted from 1980 to 1982 show that the demand rate has dropped to an average of 0.10 mg/l/day and the area of anoxia has been reduced to 4,870 km^2. This improvement in bottom water quality can be attributed to decreased amounts of sedimented organic material due to nutrient reduction.

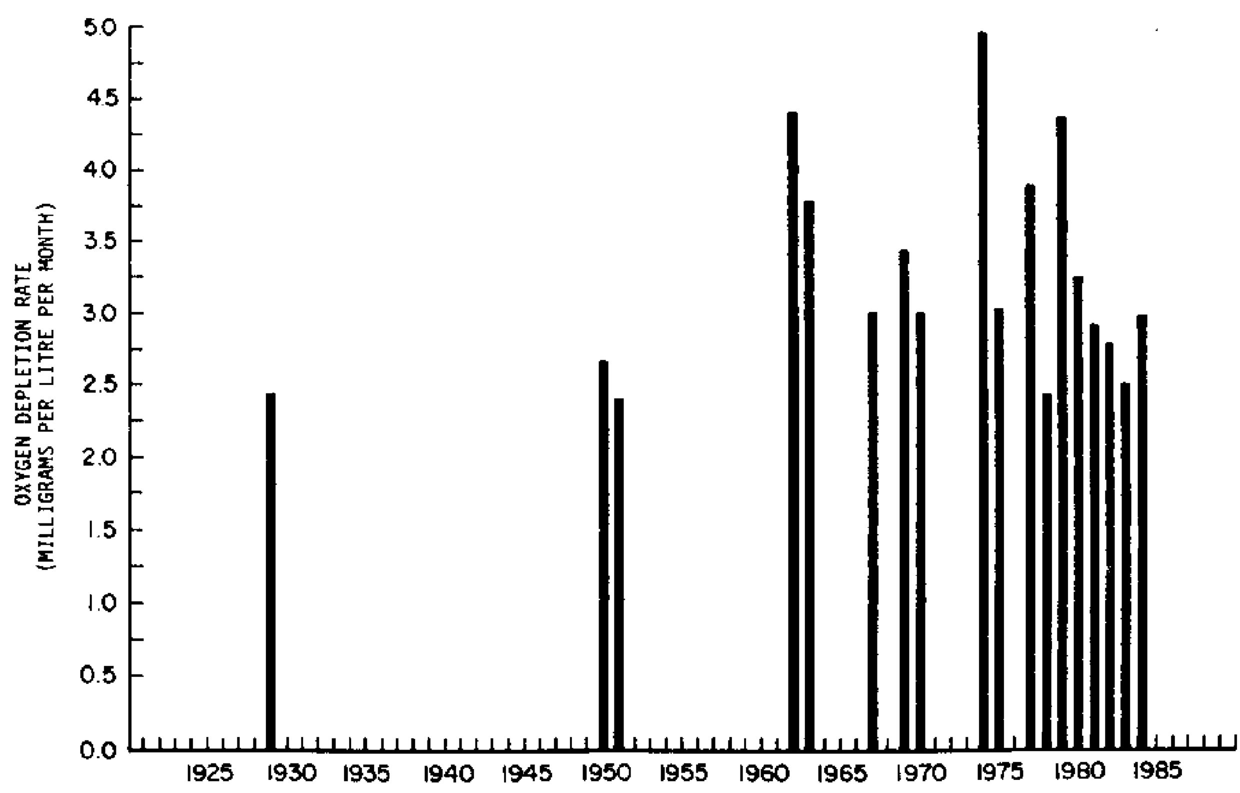
Algal Response

In response to lower phosphorus concentrations basin-wide, blooms of planktonic blue-green algae (e.g. *Microcystis*, *Aphanizomenon*, and *Anabaena*) in western Lake Erie, and massive growths of attached filamentous green algae (e.g. *Cladophora*) which were so prevalent in the mid-1960s decreased in intensity and number during the 1970s, and no basin-wide blooms have been reported in recent years. Open lake phytoplankton analysis between 1970 and 1980 indicates a reduction in total

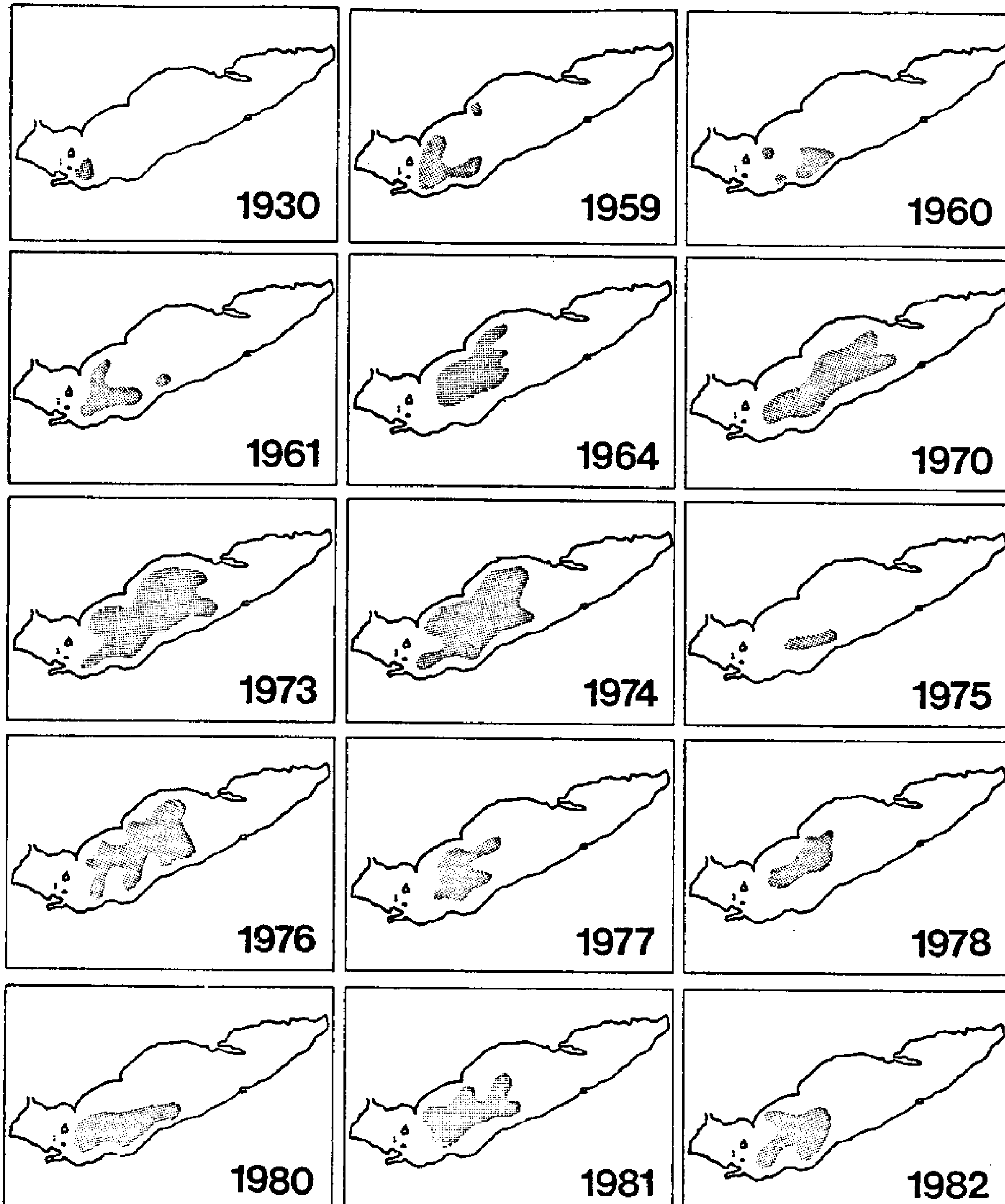
CHEMICAL CHARACTERISTICS OF CENTRAL LAKE ERIE



JULY HYPOLIMNION OXYGEN DEPLETION RATES FOR THE CENTRAL BASIN OF LAKE ERIE, 1929-1984.



DISTRIBUTION OF ANOXIA IN LAKE ERIE (1930 - 1982)



phytoplankton biomass and a composition shift toward more oligotrophic species. Eutrophic species (e.g. Melosira granulata, Stephanodiscus tenius and S. niagara) were less abundant in 1979 than in 1970, and oligotrophic species (e.g. Dinobryon divergens and Ochromonas scintillans) were first observed in 1979.

Water levels in Lake Erie during the past decade have averaged 2 ft. above the 1960-1970 levels. The difference between the lowest year (1964) and the highest year (1973) is 3.6 ft., an increase of approximately 7% in lake volume. The dilution effect of more upper Great Lakes water flowing into Lake Erie, coupled with greater submergence of algal attachment sites, is thought to be partially responsible for the absence of basin-wide algal blooms and massive growths of the filamentous algae, Cladophora, that were so prevalent in the mid-1960s.

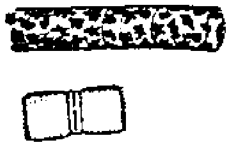
Benthos Response

The composition of the benthic macroinvertebrate communities of western Lake Erie has improved since 1967. Samples taken in 1979, when compared with 1967 data, showed that the bottom is still dominated by pollution tolerant tubificid worms (e.g. Limnodrilus hoffmeisteri, L. cervix and L. maumeensis); however, other less tolerant taxa of tubificids (e.g. Peloscolex spp.) were also common. The density of tubificid worms declined sharply at the mouth of the Detroit River between 1967 (13,000/m^2) and 1979 (2,400/m^2), while the number at the mouth of the Maumee River has remained constant. Midge (Chironomidae) larvae represented only 6% of the western basin benthic population in 1967 but rose to 20% by 1979, replacing some of the tubificids.

A modest reestablishment of the burrowing mayfly (Hexagenia limbata) has been observed at the mouth of the Detroit River and in adjacent areas of western Lake Erie. This species was extirpated from the western basin in the mid-1950s following periods of anoxia in this normally unstratified portion of the lake. Prior to 1953, bottom sediments yielded about 400 nymphs per square meter in the Bass Islands region. Following the catastrophic kills of the 1950s, no Hexagenia nymphs were found in Lake Erie sediments for over 20 years. In 1979, 20 nymphs were collected near the mouth of the Detroit River and for the past several years a small emergence of adults has been observed on South Bass Island.

Fishery Response

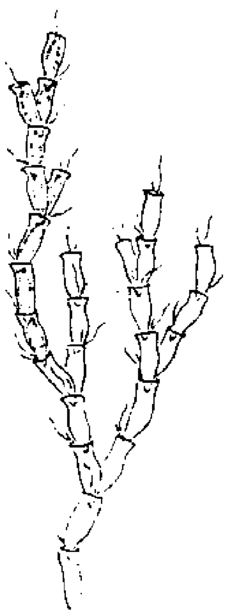
The annual sport angler harvest of fish in the Ohio waters of Lake Erie has increased from 1.4 million lb in 1976 to 10.1 million lb in 1982, an increase of 40%. During this eight-year period, yellow perch (Perca flavescens) harvests rose from 8.2 million fish to 12.2 million fish while walleye (Stizostedion v. vitreum) production jumped from 112,000 fish to 3.1 million fish.



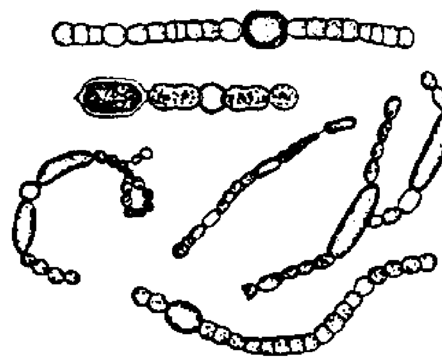
Melosira

Cladophora

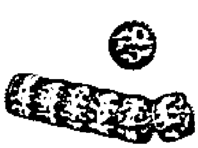
Microcystis



Dinobryon



Anabaena

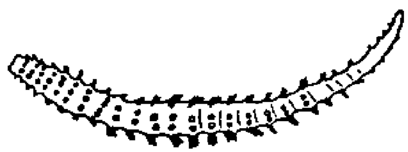


Stephanodiscus

Aphanizomenon

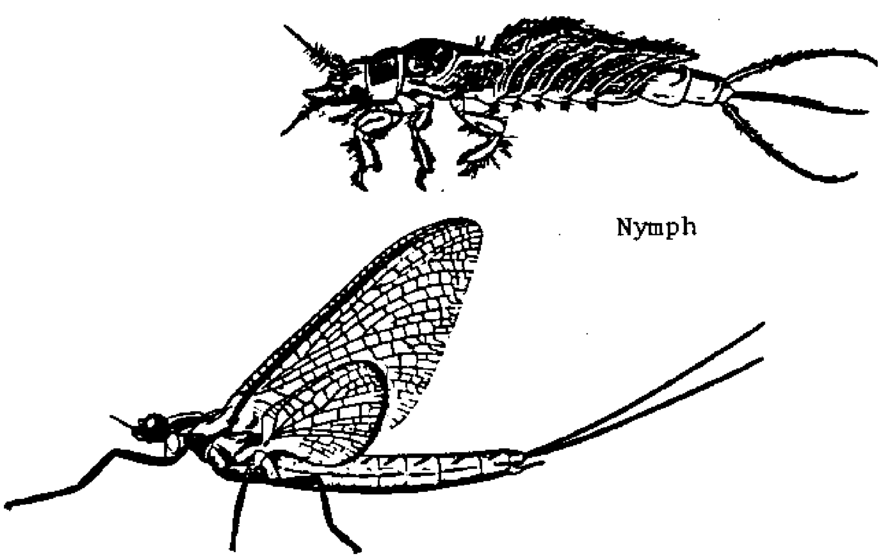
SOME LAKE ERIE ALGAL SPECIES

SOME LAKE ERIE BENTHIC SPECIES

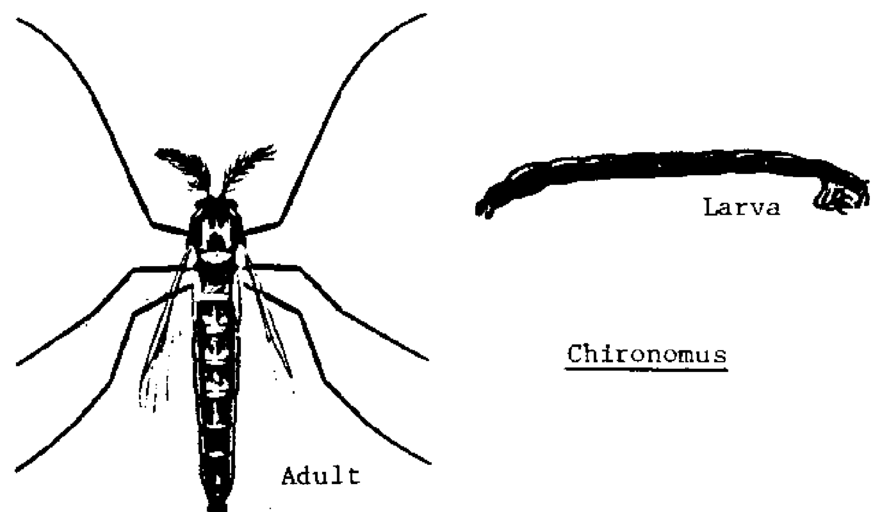


Limnodrilus

Peloscolex



Hexagenia



Chironomus

The increased walleye production has been attributed to good young-of-the-year recruitment and international management approaches to control sport and commercial harvests. The abundance of walleye within western Lake Erie also increased dramatically from 1970 to 1982. During the 1960s and early 1970s the "fishable" population of walleye (14.5 inches in length and larger) was estimated at or below two million individuals. Since 1982, the fishable population in western Lake Erie has averaged over 20 million walleye.

Database

In many respects Lake Erie has one of the longest and most complete historical databases in the Great Lakes. Early studies of Lake Erie focused mainly on bacterial contamination in nearshore waters (IJC 1918). The first detailed limnological surveys of Lake Erie were completed in 1928-1930 (Fish 1960, Wright 1955). In the 34 years following that 1928-1930 effort there were occasional surveys of limited geographical and temporal scope (e.g. Chandler and Weeks 1945, Curl 1959, Rodgers 1961, Beeton 1963). It was not until 1963/1964 that the next major study was completed (FWPCA 1968a), which was followed by another comprehensive study in 1967 (FWPCA 1968b). A notable research and surveillance effort was occasioned in 1970 (Burns and Ross 1972, Burns 1976). This was followed by a series of studies from 1973 through 1977, (Herdendorf 1977, 1979, 1980) then by two years of binational intensive studies in 1978/1979 (Herdendorf 1983, Rathke 1984). Additional annual surveys followed in 1980 through 1984 (Fay and Herdendorf 1981, Fay 1982, Fay et al. 1983, Rathke and Fay 1985). These studies represent 5 years of nearly continuous effort to determine the impact of culturally induced eutrophication and contamination from toxic substances and to assess the success of efforts to reduce those impacts. Within the last year, Burns (1985) and Rathke and Edwards (1985) have attempted to document the status of Lake Erie and trace its long- and short-term water quality trends.

In summary, during the late 1970s changes began to occur which are continuing in the early 1980s: nutrient loading declined, phosphorus concentrations in the lake dropped, sources of contamination by several toxic substances have been checked, levels of contaminants in lake sediments and biota are subsiding, "clear water" forms of plankton and benthos are showing modest signs of recovery and fish populations are rebounding. However, cause and effect relationships of all of these changes are not obvious, most of the improvements have been small, and for many parameters, conclusive trends have yet to be established. But evidence for improvement is beginning to mount and it is becoming obvious to scientists, fishermen and shoreline dwellers alike that Lake Erie is recovering. The extent of future improvements will depend on continuing efforts to control loading of nutrients and toxic substances to the lake, particularly those associated with industrial and agricultural practices. Surveillance of Lake Erie water, biota, and sediment conditions must continue if we are to establish clear relationships between remedial actions and lake quality.

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UNDERSTANDING RECENT HIGH GREAT LAKES WATER LEVELS[1]

by

Thomas E. Croley II[2]

INTRODUCTION

The Great Lakes are one of our greatest water resources, containing 95 percent of the nation's and 20 percent of the world's fresh surface water. The prime measures of water quantity are the lake levels of the individual Great Lakes and Lake St. Clair. Due to the continuing record high lake levels which began in the spring of 1985, there has been renewed interest in lake level trends and in factors accounting for the current high water levels. Many riparian interests are particularly concerned about continuing storm damage and flooding as we head towards the fall storm season on the lakes.

There is a major tendency to think of Great Lakes water levels in terms of extremes rather than of normal conditions. Within recent memory we have had the record low lake levels of 1964. This resulted in docks sitting out of the water, insufficient depths for navigation in many harbors and channels and greatly reduced recreational opportunities. These low levels were followed nine years later in 1973 by record high lake levels with resultant flooding and shore damage and erosion. The lake levels have remained high over the intervening period and new record highs were once again set on Lakes Superior, Michigan-Huron, St. Clair, and Erie.

This paper presents the physical characteristics of the Great Lakes from a water quantity perspective, outlines the basin and lake hydrologic cycles, summarizes the climatology of the Great Lakes, examines the types of natural lake level fluctuations and their causes, compares the natural fluctuations with existing diversions, describes current conditions, and concludes with a long-term perspective on lake levels.

PHYSICAL SYSTEM

The Great Lakes basin, shown in Fig. 1, contains an area of approximately three hundred thousand square miles, about one third of which is water surface. Cursory descriptions are given by Freeman and Haras (1978), the U. S. Army Corps of Engineers (1985), and the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (1977). The basin extends some 2000 miles from the western edge of Lake Superior to the Moses-Saunders Power Dam on the St. Lawrence river. The water surface drops in a cascade over this distance some 600 feet to sea level. The most upstream, largest, and deepest lake, is

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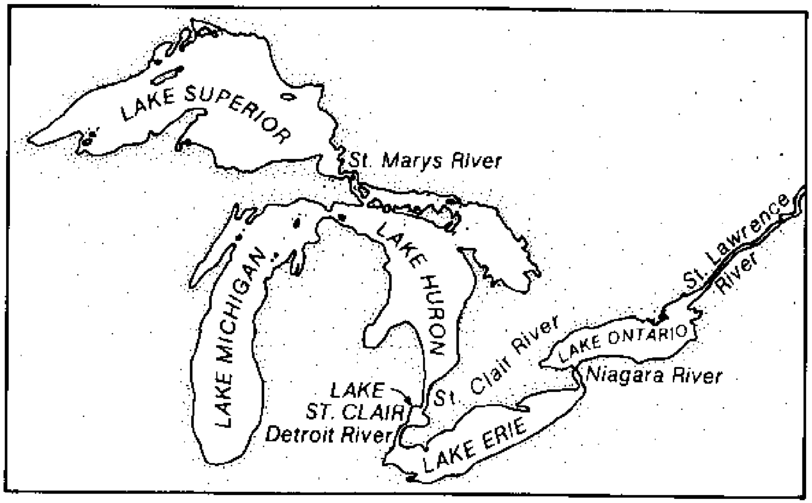

Fig. 1. Great Lakes Basin.

Lake Superior. Lake Superior is completely regulated according to a regulation plan, Plan 1977, under the auspicies of the International Joint Commission (International Lake Superior Board of Control, 1981,1982). The lake has two interbasin diversions of water into the system from the Hudson Bay Basin, the Long Lac and Ogoki Diversions. Lake Superior waters flow through the lock and compensating works at Sault St. Marie, and down the St. Marys River into Lake Huron where it is joined by water flowing from Lake Michigan.

Lakes Michigan and Huron are considered to be one lake hydraulically, because of their connection through the deep Straits of Mackinac, and together have a vast surface area that provides a buffer to flow changes leaving the lake. The second interbasin diversion takes place from Lake Michigan at Chicago. Here water is diverted from the Great Lakes to the Mississippi River Basin. The water flows from Lake Huron through the St. Clair River, Lake St. Clair, and Detroit River system into Lake Erie. The drop in water surface between Lakes Michigan-Huron and Lake Erie is only about 8 feet. This results in a large backwater effect between Lakes Erie, St. Clair, and Michigan-Huron; changes in Lakes St. Clair and Erie levels are transmitted upstream to Lakes Michigan and Huron. From Lake Erie the flow is through the Niagara River and Welland Diversion into Lake Ontario. The major drop over Niagara Falls precludes changes on Lake Ontario from being transmitted to the upstream lakes. The Welland Diversion is an intrabasin diversion bypassing Niagara Falls and is used for navigation and hydropower. There is also a small diversion into the New York State Barge Canal System which is ultimately discharged into Lake Ontario. Lake Ontario is also completely regulated in accordance with Regulation Plan 1958D. The outflows are controlled by the Moses-Saunders Power Dam between Massena, New York and Cornwall, Ontario. From Lake Ontario, the water flows through the St. Lawrence River to the Gulf of St. Lawrence and the ocean.

HYDROLOGIC CYCLE

The primary process that determines the lake levels is the hydrologic cycle of the Great Lakes Basin (Croley, 1983). As shown in Fig. 2, precipitation enters the snowpack, if present, and is then available as snowmelt depending mainly on air temperature and solar radiation. Snowmelt and rainfall partly infiltrate into the soil and partly run off directly to rivers, depending upon the moisture content of the soil. Infiltration is high if the soil is dry and surface runoff is high if the soil is saturated. Soil moisture evaporates or is transpired by vegetation depending upon the types of vegetation, the season, solar radiation, air temperature, humidity, and wind speed. The remainder percolates into deeper basin storages which feed the rivers and lakes through interflows and groundwater flows. Generally, these river supplies are high if the soil and groundwater storages are large. Because of this buffering effect of the large snowpack and the large soil, groundwater, and surface storages, runoff from rivers into a lake can remain high for many months or years after high precipitation has stopped.

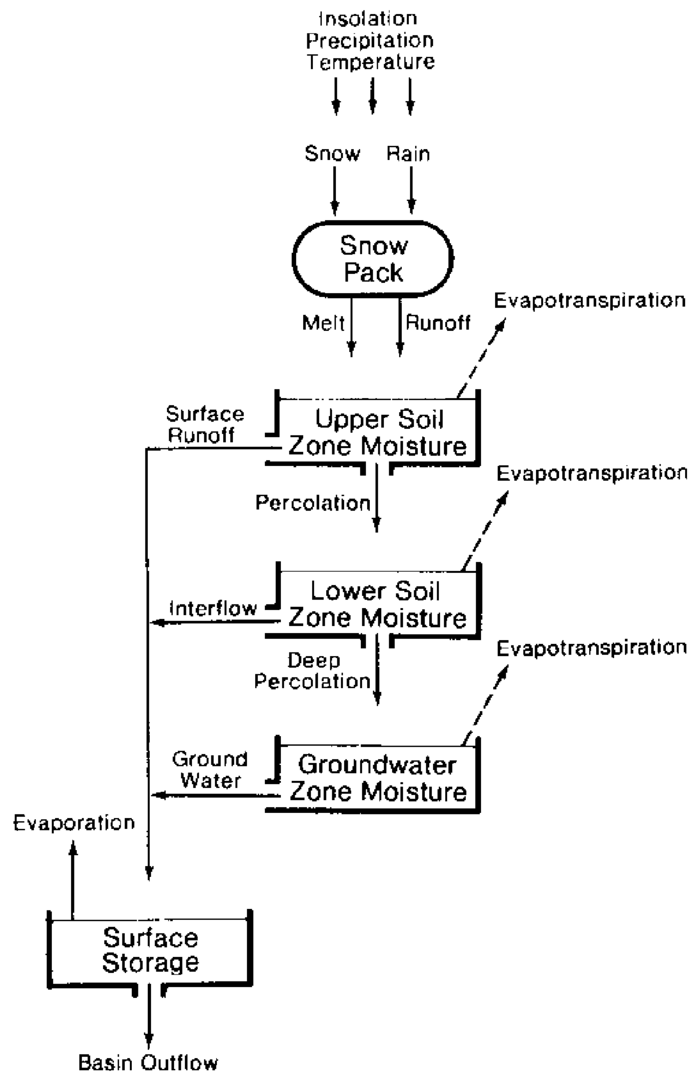

Fig. 2. Runoff Hydrology Concepts.

Major sources of water into a lake include precipitation on the land basin which results in runoff into the lake, precipitation over the lake surface, inflow from upstream lakes, and diversions into the lake. Net groundwater flows directly to each of the Great Lakes are generally negligable (DeCooke and Witherspoon, 1981). The outflows consist of evaporation from the lake surface, flow to downstream lakes, and diversions. The imbalance between the inflow and outflow results in the lake levels either rising if there is more inflow than outflow, represented by a positive change in storage, or falling if there is more outflow than inflow, represented by a negative change in storage.

CLIMATOLOGY

Precipitation causes the major long term variations in lake levels (Quinn and Croley, 1981). Figure 3 depicts total annual precipitation over Lakes Michigan-Huron, St. Clair, and Erie for the 1900-79 period (Quinn, 1981; Quinn and Norton, 1982). From 1900 through 1939, a low precipitaion regime predominated with the majority of the years falling below the mean. From about 1940 to date, a high precipitation regime has existed. Of particular interest is the high precipitation in the early 1950's, the low precipitation in the early 1960's that led to the record lows, and a consistently very high precipitation regime from the late 1960's through the present time. Table 1 summarizes Great Lakes annual precipitation totals by basin for several periods. Of particular interest are the progressions of increasing precipitation for each basin. While the 1940-85 period is above normal (from 3 to 7% higher), the last 15 year period is higher still (6 to 11%); last year set many new records with the highest precipitation to date (23 to 39% higher for the upper lakes).

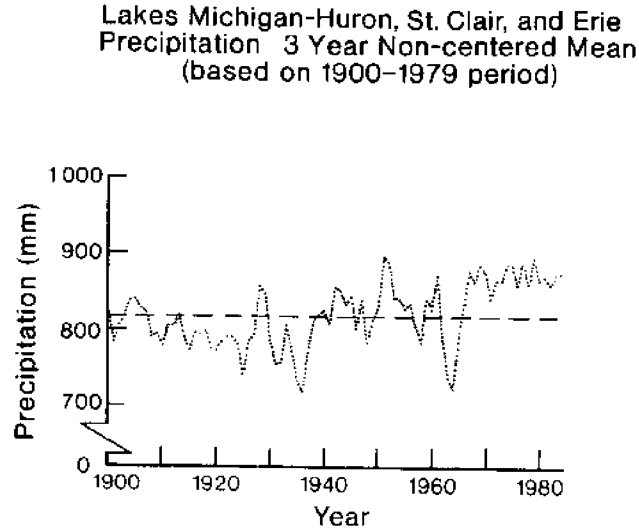

Fig. 3. Historic Precipitation.

Table 1. Great Lakes Annual Precipitation Summary.

Period	Superior (in)	Superior (%)	Michigan (in)	Michigan (%)	Huron (in)	Huron (%)	Erie (in)	Erie (%)	Ontario (in)	Ontario (%)
Normal[a]	29.6	100	31.1	100	31.5	100	34.1	100	34.3	100
1900-39 (low)	28.5	96	30.8	99	30.5	97	33.5	98	33.8	99
1940-85 (high)[b]	31.8	107	32.0	103	33.6	107	35.8	105	35.6	104
1970-85[b]	33.0	111	32.9	106	35.0	111	37.4	110	37.0	108
1985[b]	41.2[c]	139	38.2[c]	123	41.6[c]	132	42.0	123	36.9	108

[a]Normal is defined as the mean for the period 1900-69.
[b]June-December 1985 provisional data from the U. S. Army Corps of Engineers (Detroit District).
[c]Record high for 1900-85.

Variations in air temperature also influence lake level fluctuations. At higher air temperatures, plants tend to use more water, resulting in more transpiration, and there are higher rates of evaporation from the ground surface. This yields less runoff for the same amount of precipitation than would exist during a low temperature period when there is less evaporation and transpiration. The annual mean air temperature around the perimeter of the Great Lakes since 1900, summarized in Fig. 4, indicate three distinct temperature regimes; a low temperature regime from 1900 to

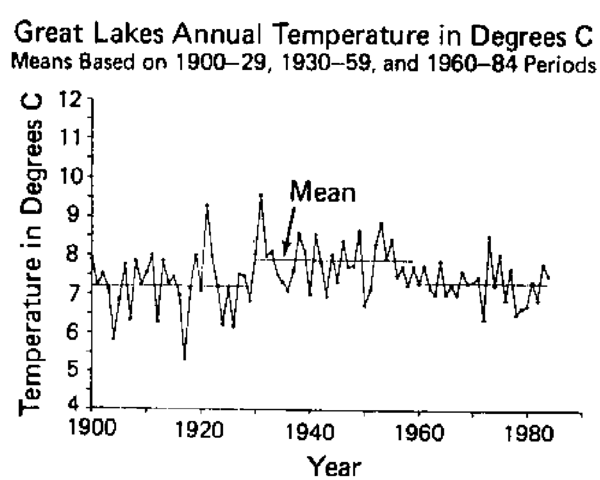

Fig. 4. Historic Air Temperature.

1929, a higher temperature regime from about 1930 to 1959 and an additional low regime from 1960 through the present period. The difference between the previous and current regime is a drop of about 1 degree Fahrenheit.

The magnitude of the hydrologic variables vary with the season, as shown in Fig. 5 for Lake Erie (Quinn, 1982; Quinn and Kelley, 1983). The monthly precipitation is fairly uniformly distributed throughout the year, while the runoff has a peak during the spring which results primarily from the spring snowmelt. The runoff is at a minimum in the late summer and early fall due to large evapotranspiration from the land basin. The lake evaporation reaches a minimum during the spring and gradually increases until it reaches a maximum in the late fall or early winter. The high evaporation period is due to very cold dry air passing over warm lake surfaces. The integration of these components is depicted in the net basin supply, which consists of the precipitation plus the runoff minus the evaporation. The net basin supply is seen to reach a maximum in April and a minimum in the late fall. The negative values indicate that more water is leaving the lake through evaporation than is being provided by precipitation and runoff.

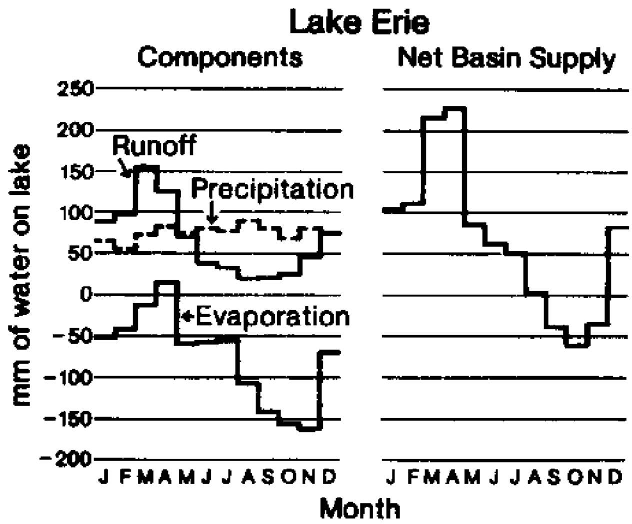

Fig. 5. Seasonal Net Basin Supply.

LAKE LEVEL FLUCTUATIONS AND TRENDS

There are three primary types of lake level fluctuations: annual lake levels, seasonal lake levels, and short-period lake level changes due to wind setup and storm surge. Annual fluctuations result in most of the variability leading to the record high and low lake levels. The annual lake levels are shown in Fig. 6 from 1860 through the present to illustrate the long-term variablity of the system. The record highs in 1952 and 1973 and record lows in 1935 and 1964 are readily apparent. There is an overall range of about 6 feet in the annual levels. Of particular interest is the fall in the levels of Lakes Michigan and Huron occurring in the mid-1880's from which the lakes never recovered.

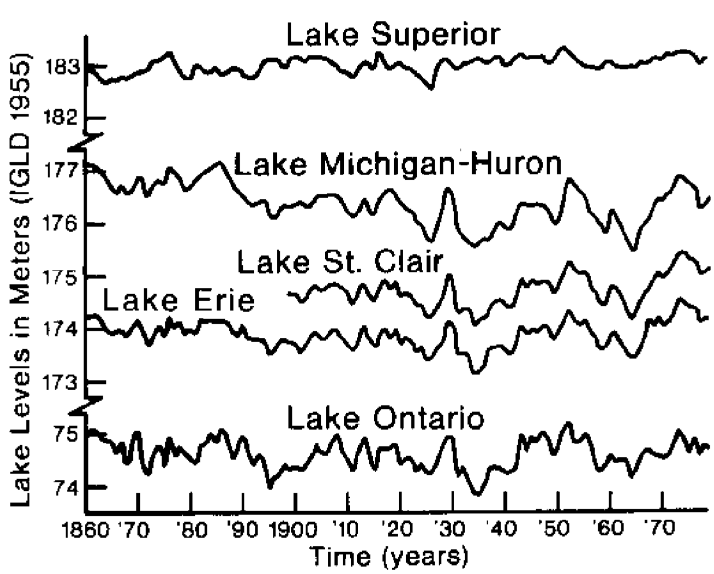

Fig. 6. Historic Great Lake Levels.

This probably results from dredging for deeper draft navigation in the St. Clair River. Other changes in the St. Clair River include sand and gravel dredging between about 1908 and 1924, a 25-foot navigational project in the mid-1930's, and a 27-foot navigation project in the late 1950's and early 1960's. Without these changes Lake Michigan-Huron would be approximately 1.5 feet higher than it is today.

The three-year non-centered precipitation mean in Fig. 3 correlates very well with annual lake levels as observed by superimposing the annual precipitation on the annual Lake Erie water levels in Fig. 7. The precipitation tends to lead the water levels by approximately one year, as shown here by the 1929 high's, the 1935 low's, and the 1952 high's. In particular you can see the results of the last 15 years of high precipitation resulting in very high water levels. Thus, the continuing high levels are the result of the increased precipitation regime since 1940 coupled with the lower temperature regime since 1960.

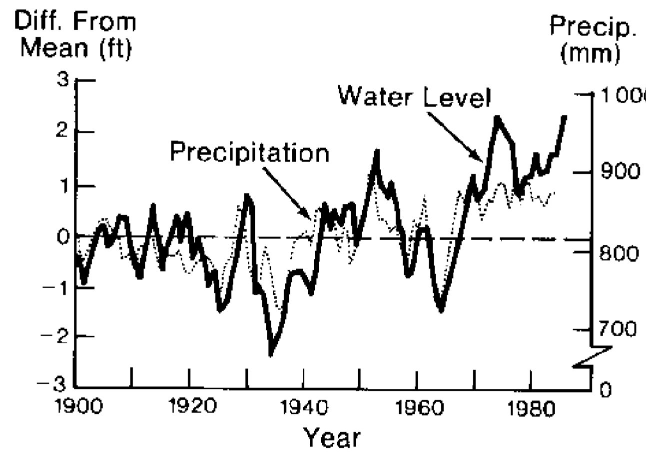

Fig. 7. Annual Lake Erie Water Levels

Superimposed on the annual levels are the seasonal cycles shown in Fig. 8; each lake undergoes a seasonal cycle every year. The magnitude depends upon the individual water supplies. The range varies from about 1.5 feet on Lakes Erie and Ontario to about 1.0 foot on Lake Superior. In general, the seasonal cycles have a minimum in the winter, usually January or February. The levels then rise due to increasing water supplies from snowmelt and spring precipitation until they reach a maximum in June for the smaller Lakes, Erie and Ontario, and September in the case of Lake Superior. When the net water supplies diminish in the summer and fall, the lakes begin their seasonal decline.

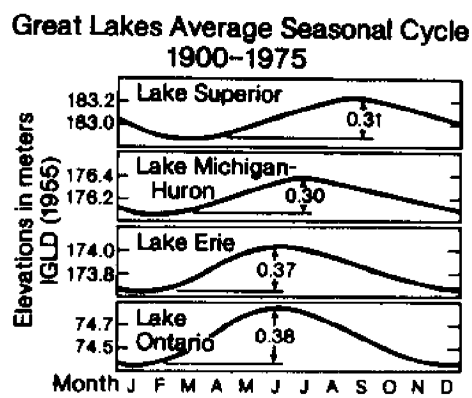

Fig. 8. Seasonal Cycles.

The final type of fluctuation which is common along the shallower areas of the Great Lakes, particularly Lake Erie, Saginaw Bay, and in some cases on Green Bay, are storm surges and wind set-up. Under these conditions when the wind is blowing along the long axis of a shallow lake or bay, a rapid difference in levels can build up between one end of the lake and the other. This difference can be as large as 16 feet for Lake Erie. These storm conditions, when superimposed on high lake levels, cause most of the damage along the Great Lakes shoreline.

Looking in more detail at the past trends in lake levels, along with the more recent conditions for Lake Erie, we see a steady progression of changes in the lake levels with time in Fig. 9. These changes reflect the changes in precipitation, illustrated in Fig. 3 and summarized in Table 1. At the bottom of Fig. 9 are the record low lake levels for each month which were set primarily in 1964. Proceeding upwards we have the 40-year average from 1900 to 1939. From 1940 to 1979, the lake is at a still higher average level. Taking the 11-year period from 1970 to 1980, we see that the lake level average is higher yet, followed by the record highs set in 1973. In 1985, record levels were set in April and May on Lakes Michigan-Huron, St. Clair, and Erie.

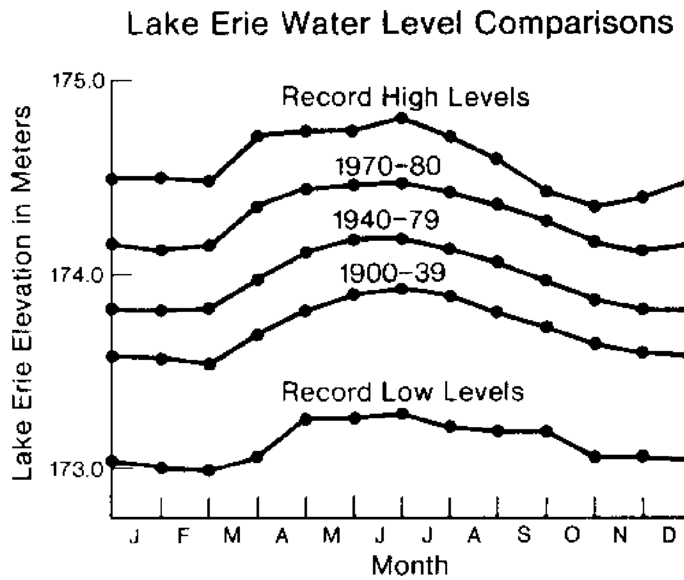

Fig. 9. Lake Erie Level Comparisons.

DIVERSIONS

It is interesting to compare the impacts of the existing diversions on lake levels in Table 2 with natural lake-level fluctuations (International Great Lakes Diversions and Consumptive Uses Study Board, 1985). This enables a comparison of man's impacts with natural fluctuations. The Long Lac and Ogoki Diversions average about 5,600 cfs. They raise Lake Superior by about 0.21 ft, Lake Michigan-Huron by 0.37 ft, Lake Erie by 0.25 ft, and Lake Ontario by 0.22 ft. The Chicago Diversion averages about 3,200 cfs and lowers Lake Michigan-Huron by 0.21 ft, lowers Lake Superior by 0.07 ft, Lake Erie by 0.14 ft, and Lake Ontario by 0.10 ft. The Welland Canal, which bypasses Niagara Falls, averages about 9,400 cfs and lowers Lake Superior by about 0.06 ft, Lake Michigan-Huron by about 0.18 ft, Lake Erie by 0.44 ft, and has no effect on Lake Ontario. The combined effect on the lakes ranges from a plus 0.11 ft for Lake Superior to a -0.33 ft for Lake Erie. The combined effect on Lake Michigan is only -0.02 ft and on Lake Ontario 0.08 ft. The diversion effects are therefore small in comparison with the 1.5-foot seasonal cycle and the 6-foot range of the annual variations.

Table 2. Impact of Existing Diversions on Lake Levels.

Diversion	Amount (cfs)	Superior (feet)	Mich-Hur (feet)	Erie (feet)	Ontario (feet)
Ogoki-Long Lac,	5,600	+ 0.21	+ 0.37	+ 0.25	+ 0.22
Chicago,	3,200	- 0.07	- 0.21	- 0.14	- 0.10
Welland,	9,400	- 0.06	- 0.18	- 0.44	0
COMBINED		+ 0.07	- 0.02	- 0.33	+ 0.08

The small effects of the diversions along with the long response time of the system illustrate why diversions are not suitable for lake regulation. Due to the large size of the Great Lakes system it responds very slowly to man-induced changes. This is illustrated in Fig. 10 by the length of time it takes from the start of a hypothetical diversion on Lakes Michigan and Huron (of the magnitude of the Chicago diversion) until the ultimate effect of that diversion is reached on Lakes Michgan-Huron, and Erie. It takes approximately three to three and one/half years to achieve 50 percent of the ultimate effect and 12 to 15 years to get 100 percent of the effect. Thus, regulation by diversion would not produce changes responsive to natural fluctuations. Recent studies at the Great Lakes Research Laboratory indicate that an increase of 10% in the Niagara River discharge from Lake Erie would lower it 10.5 inches in about 11 to 12 years.

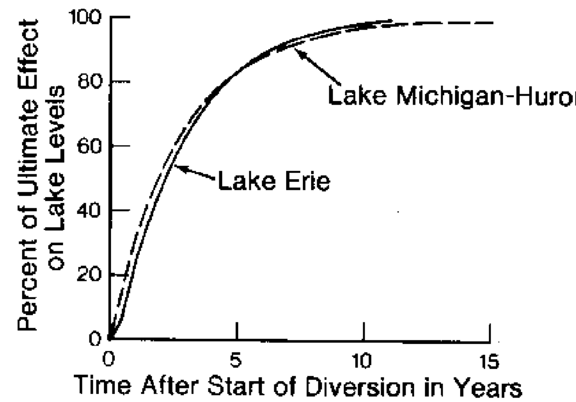

Fig. 10. Response to Diversion.

Additional interbasin diversions are a highly controversial issue at the present time around the Great Lakes. Possible uses of Great Lakes water outside the basin are flow augmentation for navigation, energy uses such as synfuels or pipelines, agriculture and aquifer recharge, and municipal water supplies. A small pipeline project such as the Powder River coal slurry pipeline would require 5-8 cubic feet per second of water and would have no measurable impact on lake levels. A synfuels project, highly unlikely at this time, could require approximately 800 cubic feet per second and result in lake level lowerings of 0.04-0.06 foot. A major agricultural or aquifer recharge project could require 10,000 cubic feet per second and would result in lake level decreases ranging from 0.4 foot on Lake Erie to 0.7 feet on Lake Michigan-Huron. It should be emphasized that these are hypothetical projections for illustration only.

CURRENT CONDITIONS

We had much higher than normal precipitation throughout the Great Lakes Basin every month from December 1984 through March 1985, sometimes ranging 100% higher than normal in some parts of the basin. A major spring snowmelt also occurred during the last week in February 1985, compounding the problem. On 18 February 1985, there was a large snow cover throughout the Great Lakes Basin. One week later most of the snow in the southern part of the basin melted and quickly ran off causing the lake levels to rise. April through June of 1985 was dry to normal but every month from August through December of 1985 was again very wet with August and September 100% higher than normal in some parts of the basin. Air temperatures throughout the summer were below normal, reducing transpiration and evaporation. Air temperatures were close to normal throughout the fall and lower than normal during the winter, resulting in major snowpack storage. In March of 1986, both precipitation and air temperatures were higher than normal, resulting in snowmelt runoff which kept the lake levels high.

The results of these conditions for January through May 1985 are shown in Fig. 11 as they affect water levels for Lakes Erie, St. Clair and Michigan-Huron; also shown are the record monthly mean levels established during 1973. At the start of 1985, the lake levels were below the record levels. The effect of the February 1985 snowmelt is shown by the sudden rise, in Fig. 12, of Lakes Erie and St. Clair. The lakes began exceeding the record levels in March. Heavy rains on the southern portion of the basin occurred in late March and early April of 1985, which resulted in Lakes Erie and St. Clair setting new record highs in April. Lake Michigan-Huron also set record high levels but rose at a much slower rate due to its very large water surface, roughly 45,000 square miles. The record high levels continued in May 1985, but due to the dryer conditions on the basin no June records were set.

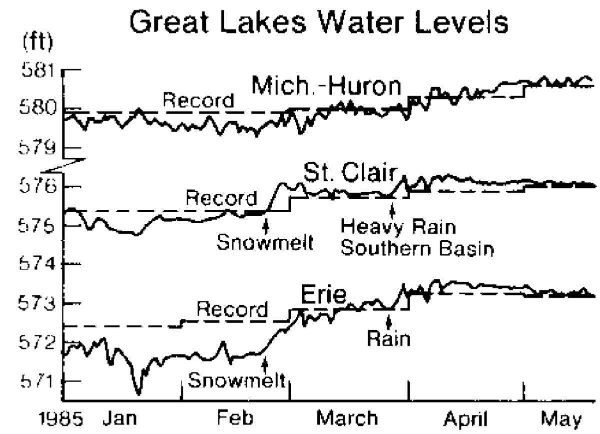

Fig. 11. 1985 Daily Lake Levels.

Similarly, for July 1985 through April 1986, water levels and record monthly means are shown in Fig. 12 for Lakes Erie, St. Clair, and Michigan-Huron. Lake levels continued to be high but slightly under record levels on Lakes Erie and St. Clair from July through September or October 1985. In November 1985, levels on these two lakes again began exceeding the records; this continued through April 1986. Lake Michigan-Huron, while high, set no new records.

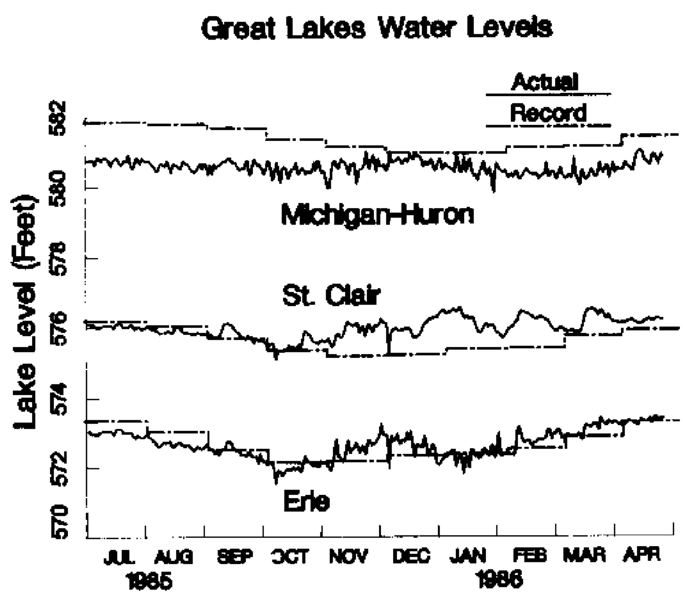

Fig. 12. 1985-86 Daily Lake Levels.

FUTURE

Water supplies will not change fast, as shown by the above consideration of diversions. Other studies at the Great Lakes Enviromental Research Laboratory indicate that if normal meteorological conditions were again realized ("normal" being the average conditions over 1900-69), it would still take about 6 years for Lake Michigan-Huron to return from its January 1986 level to its normal (1900-69) level. About 7 years are required for Lakes St. Clair and Erie to return to within 4 inches of normal and about 9 years are required for them to return to within 2 inches of norml. Even supposing that we encountered a drought similar to the 1960-64 conditions, about 3.5 years are still required for Lake Michigan-Huron and about 4 years are required for Lakes St. Clair and Erie.

A long-term perspective on Lake Michigan levels for 7000 years was reconstructed through geologic and archaeologic evidence by Curtis Larson (Larson, 1985) under work sponsored by the Illinois Geologic Survey. Conditions back several thousand years ago were not necessarily the same as today due to isostatic rebound and uplift during the intervening time. But, in general, this provides us with additional perspective on possible conditions we may experience in the future. Looking at just the last 2500 years, during which time the Great Lakes were in their current state, there were major lake level fluctuations. During most of this time the levels were much higher and more variable than they have been during the last 120 years of record. If the past is any indication, lake levels in the future could go through a considerably larger range than we have experienced lately. Indeed, the period of record which makes up what many consider to be normal, the early 1900's through the 1960's, may be abnormal conditions.

CONCLUSIONS

As we enter this fall storm season, the Great Lakes are experiencing record or near-record high lake levels, except for Lake Ontario, making it highly likely that riparian interests will experience continued flooding, erosion, and shore damage. Based upon the persistance of the current high precipitation and low air temperature regimes it is likely that the current high lake level regime will continue for the next several years. It is also important to keep in perspective that while we have ranges in annual lake levels of 4 to 6 feet, and additional short term effects on the order of 7 or 8 feet, the effects of man on the system are relatively small, on the order of a couple of tenths of a foot. Therefore man can have relatively little impact in bringing about major reductions of the existing high lake levels.

ACKNOWLEDGMENT

This report relied extensively on presentations of, and other materials gathered by, Dr. Frank H. Quinn, and on studies performed by Ms. Holly C. Hartmann, both from the Great Lakes Environmental Research Laboratory.

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LAKE ERIE COASTAL USES

RICHARD BARTZ

Ohio Department Of Natural Resources

I have been asked to talk about Lake Erie coastal uses. I would like to discuss briefly how we use our coastal resources in Ohio by giving you an overview of Lake Erie shoreline uses.

Before I discuss coastal uses however, I would first like to give you some general statistics about Lake Erie and Ohio. For the purposes of our presentation today, we have about 265 miles of Lake Erie shoreline, which includes the mainland, islands, and bays. Of the 9,900 square miles of Lake Erie, about one-third or 3,300 square miles are in Ohio. Part or all of 34 of the 88 counties in Ohio are in the Lake Erie drainage basin and about 40% of Ohio's population. We generally like to say that about one-third of the geographic area of Ohio is in the Lake Erie drainage basin.

Lake Erie is an interstate resource. We share it with Michigan, Pennsylvania and New York. Lake Erie is also an international resource. We share it with the Province of Ontario.

During my presentation I'm going to refer to the western basin and the central basin. Very basically the central basin is from Sandusky, Ohio, to Conneaut, Ohio. The western basin is from Sandusky, Ohio, west.

The physical features along the Lake Erie shoreline affect how we use Lake Erie. The shore types themselves influence how we use Lake Erie. In the central basin, high bluffs front the Lake Erie shoreline. In the Sandusky area the bluffs are about five or six feet high. In the far eastern part of Ohio the bluffs may be 40 to 50 ft. high. These bluffs are primarily susceptible to erosion. In the central basin we only have flooding at the river mouths. The western basin of Lake Erie is fronted by low plains which are susceptible to both flooding and erosion. The drainage area of the western basin is characterized by being very flat and very low. During storm events we have flooding one to two miles inland because of the low relief. In the western basin we have remnants of a barrier beach-wetland system that used to go from Sandusky, Ohio, to Toledo and then on up to Detroit. This is characterized by a barrier beach all along the shoreline with wetlands behind it.

The presence or absence of the beach affects how we use the shoreline. In 1974 the Division of Geological Survey came up with some statistics on the amount of beach along the shoreline. They found that 52% of the shoreline had a beach zone. Forty-eight percent of the shoreline was without a beach. Since we have had high lake levels for the last 16 years, I would venture to say that the area without a beach zone has increased.

Habitat. The first type of coastal uses I want to talk about are the in-stream uses or in this case the in-lake uses. In talking about coastal uses these are often overlooked.

First and foremost Lake Erie provides wildlife and aquatic habitat. Lake Erie is habitat for benthic communities, fisheries and waterfowl. It is the most diverse of all the Great Lakes because it is so shallow.

Water quality. There is an old adage that goes "the solution to pollution is dilution." To some extent that still is true. We continue to use Lake Erie to dispose of our municipal and industrial waste. We have made great strides in working towards improving our water quality. We have improved all of our treatment plants to secondary treatment for municipalities. Industries have also improved their treatment. We are getting close to meeting our goal for phosphorous input into the lake. Most of the gains that we will achieve in the future will be from our non-point sources. Ohio is developing a program to work with farmers in 25 counties in the Lake Erie basin in northeast Ohio, Indiana and Michigan. These programs are designed to encourage conservation tillage and other tillage practices in order to reduce soil erosion and to decrease phosphorus. It is estimated that between one and two million acres of farmland will have to be put into conservation tillage and/or no tillage type practices in order to meet these goals.

Commercial navigation. It serves a very important role to Ohio's economy. In 1979 we saw up to 98 million tons of goods move in and out of Ohio's Lake Erie ports. The highest year for shipments on Lake Erie was 1979. Ninety percent of that 98 million tons of goods was in four commodities: grain, limestone, coal, iron ore. We can see from this that our ports and the commercial navigation are very important to Ohio's agriculture, steel, and our power industry. These 98 million tons of goods have been estimated to be a $1.4 billion impact to Ohio's economy.

Recreational boating. Nearly one-fourth of all the boats registered in Ohio list Lake Erie as their primary area of use. That represents over 70,000 boats using Lake Erie in Ohio alone. The economic value of the boating industry on Lake Erie has been estimated at $133,000.000 a year.

Fishing. In 1985 we harvested 11.8 million pounds of fish from Lake Erie. Of this, 3.5 million pounds were harvested by our commercial fishermen and 7.8 million pounds were harvested by our recreational sport fishermen. The great success on Lake Erie has been the walleye fishery. Lake Erie has been named as the walleye capital of the world and I invite you all to stay around and take advantage of the walleye fishing on Lake Erie. In 1975 we harvested 112,000 walleyes in Lake Erie. In 1985 we harvested 3.7 million walleyes from Lake Erie and that was the second highest walleye harvest in the last 11 years. The walleye sport fishery in the western basin of Lake Erie has been estimated to be a $100,000,000 a year industry. This is for the sport fishery only for walleye from private boats in the western basin. This does not include the central basin, the perch or bass fishery, or the 700 boat captains that are operating at lake Erie. So you can see that the impact of the walleye fishery is much greater than just $100,000,000 a year.

Now I would like to go over some of the other types of coastal uses or the off-stream water uses.

Water Supply. Lake Erie and the Great Lakes represent a great reservoir of water for water supply. The Great Lakes represent 20% of the world's fresh surface water and 95% of the United States fresh surface water. About 110 billion gallons per day flow past Ohio. We utilize about 4% of that or 4.3 billion gallons per day. To break that down further we use approximately 530 million gallons per day for drinking water in municipal water supply in Ohio. We utilized 628 million gallons per day for industrial processing, and 3.2 billion gallons per day for electrical generation. I want to emphasize that I'm saying "utilized" because much of the water is returned to the Great Lakes.

Commercial harbors. We have eight commercial harbors in Ohio that are maintained by the Corps of Engineers from Toledo, Ohio, in the western basin to Conneaut, Ohio, in the central basin. As a coastal use our commercial harbors are water dependent use. They are important to Ohio's economy as a cost efficient means of transportation in order to keep our product costs lower. In Ohio with the eight harbors, we have a problem in that the harbors had to be dredged to about 28 ft. below the low water datum. This is done by the Corps of Engineers. I say it is a problem from the point of view that dredging involves large quantities of materials and it is very costly. The Corps dredges the eight commercial and four recreational harbors in Ohio. In 1984 this meant dredging 2.1 million cubic yards of material at a cost of about 10.5 million dollars. Over the Great akes about 9.3 million cubic yards of material are dredged annually. Over half of that comes from Lake Erie alone. Ohio represents about 40% of all the dredging that occurs on all the Great Lakes.

The traditional method of disposing of dredged materials on the Great Lakes is to return them to the open lake. However, many of the sediments that are dredged are polluted with organics, nutrients and heavy metals. The polluted materials must be disposed of either at upland sites or in confined disposal facilities. Therefore in the last 12 years we have a new coastal use and that is the confined disposal facilities. We have built several such facilities along the Lake Erie shoreline. It's a very expensive program already costing $68,000,000. We are currently looking for new sites at both Toledo and Cleveland Harbors.

The confined disposal facility program is a water quality program. It was initiated to protect the water quality of Lake Erie and the Great Lakes overall. The problem is that the confined disposal facilities take up valuable nearshore habitat. We find ourselves having a tradeoff between protecting the water quality and decreasing nearshore habitat. An example is the confined disposal facility at Toledo Harbor which takes up 242 acres of shallow water.

Residential housing. This is a major shoreline use in Ohio. It represents 44% or about 116 miles of Lake Erie shoreline in Ohio. Generally building along the Lake Erie shoreline doesn't cause problems until the shoreline gets close to the structures. Flooding and erosion are significant problems for many shoreline property owners. A survey was done for the period of 1972-1976 to assess the damages due to shoreline flooding and erosion. We found that over $65,000,000 of damage was done during that four-year period to property along the Lake Erie shoreline. The shoreline owners spent an additional $34,000,000 during that time to protect their properties. It is very expensive to try to protect property. The cost ranges form about $150.00 per linear foot for just large stone riprap up to $2,000 per linear foot for a breakwater.

We have been experiencing record high lake levels since 1972. During the mid-1950's there was a brief period of high water levels. Essentially water levels until the last 15 years had not been significantly above the long term average for any length of time since before 1900. Most of the construction along the Lake Erie shoreline has taken place since 1900's, i.e., during low waters. As a result property owners have developed expectations regarding water levels that may not be applicable now or in the future.

Most of the damage that occurs along the Lake Erie shoreline is a result of a major storm. Lake Erie is oriented on a southwest-northeast axis. Whenever we have a significant storm which involves high winds over a long period of time, the water is literally pushed to one end of the lake causing an exceptionally high lake level. In a recent storm of December 2, 1985, we had gale force winds of over 60 miles an hour for a number of hours from the southwest. The lake level was at about 572.5 feet above sea level, which was already a record high lake level. On top of that the winds pushed 8 feet of water down towards the Buffalo area. On top of that you could add waves 10-15 ft. high. At the same time in Toledo the water levels were about 16 ft.lower. During a similar storm event from the northeast in November of 1972, the levels were at a record high lake level and we only had a set up of 4 1/2 feet, which caused 22 million dollars in damages.

Industry and commerce. We find such uses primarily around large cities and in the harbor areas. As a land use, they compose about 14% of the Lake Erie shoreline. We have six coal plants along the Lake Erie shoreline. We also have power 2 nuclear power plants, the Davis Besse plant in Ottawa County and the Perry Plant in Lake County.

Recreation. Recreational uses take up approximately 23% of the Lake Erie shoreline. We use these areas for fishing, boating, swimming, sunbathing, walking, or just viewing the lake. The Ohio Department of Natural Resources has six major state parks along the Lake Erie shoreline. DNR recently completed a study at the request of a State Representative to locate a new state park along Lake Erie shoreline. The study found that there are few if any opportunities remaining for a major new state park along the Lake Erie shoreline.

We have more than just state parks along the Lake Erie shoreline. Almost every community has one or two community parks which are designed for community needs and not regional needs. For the last several years we have seen increasing demands for more regional facilities. Through our new Lake Erie access program, DNR is trying to work with the local communities to improve the community parks to meet regional needs. An example of this is Fairport Harbor. The launch ramps originally at Fairport Harbor were just a rickety dock and a sand based launch ramp off the beach. We now have modern boat launching facilities at Fairport Harbor.

Additional public access is being provided through joint public and private ventures. An example of this is Portside in Toledo, where we have public access along the Maumee River, commercial shops, the international headquarters for Owens-Illinois and new boat slips in the park.

Wildlife and natural areas. These provide habitat and protect wetlands. Wildlife areas are managed primarily for waterfowl habitat. These wildlife areas are concentrated primarily in the western basin and are remnants of the old barrier beach-wetlands system. We have been able to protect about 20,000 acres of wetland habitat through federal-state initiatives and through private duck hunting clubs. These wildlife areas provide habitat not only for waterfowl but other species, including habitat for the bald eagle.

We have several natural areas along the Lake Erie shoreline which were preserved primarily to protect wetlands. We have four state nature preserves. A non-profit organization, The Nature Conservancy, has two projects along the lake, one at Arcola Creek and a 3,000-acre project in Sandusky Bay.

Specialty agriculture. I bring this up because it is a lake-dependent use. The lake moderates the climate along the Lake Erie shoreline for about 5 miles inland. This moderation produces a warm fall and increases the growing season. What we find along the Lake Erie shoreline are fruit farms, nurseries, and the grape industry. When we talk about coastal uses, we must consider these industries which are supported by the increased growing season along the Lake Erie shoreline.

Mineral extraction. Sand and gravel are extracted from Lake Erie from four designated areas by commercial operators. These areas are old geologic deposits and not part of the littoral system. We have two salt mines operating along the Lake Erie. The salt mines have shafts 2,000 feet deep and the mines extend out a half to one mile under the bed of Lake Erie. Natural gas extraction in Lake Erie has been occurring for some time, though none in U.S. waters. I believe over 1,000 wells have been drilled in Ontario waters. The Celeste administration has recently reaffirmed the policy of no oil or natural gas extraction in Ohio waters.

Artillery range. There is a 95 sq. mile area in the western basin of Lake Erie offshore of Camp Perry that is used as an artillery range for testing and target practice. This area is often times restricted for boat and fishing use in the summer. Through the efforts of the Sea Grant program and others we have tried to decrease the conflicts that this might cause.

The last point I want to make is on the ownership of the Lake Erie shoreline. The State of Ohio holds in trust for the people of the state the submerged lands of Lake Erie. The littoral upland owners hold everything down to the water line. The Great lakes are not like many other coastal states where the citizens have customary rights to use the tidal areas. In these other states, people grew up able to go to the beach and walk expansive lengths, picnic, go camping, swim or whatever they would want to do. In Ohio and on the Great Lakes, the beaches are held for the exclusive use of the upland owner. We can only visit beaches in the Great Lakes at public parks. We have not grown up with a close association with the Lakes as a result. Therefore, it has been difficult to foster the stewardship statewide for Lake Erie and Great Lakes programs. However with the improvement in fishery, the increasing awareness of clean freshwater, and through the work of our educators, we have seen a heightened sense of stewardship for the Lakes.

Who Governs The Great Lakes Basin?

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INTRODUCTION

Popular and scientific concerns about gradual deterioration of water quality and fish supply in the Great Lakes in the 1970s led to a renewed interest in the question, "Who is in charge? Who is making the decisions about the uses and abuses of this great resource?" The abrupt emergence in the 1980s of the issue of diversion of Great Lakes water to arid regions of the country sharply escalated discussions of the adequacy of the governmental system.

Traditionally, decisions about both water quality and water quantity in the region have been made on an ad hoc basis by both private and public authorities with little consultation among affected parties. Public indifference to the natural ecosystem had to be converted to public concern before the problems of the institutional ecosystem could be addressed.

The critical characteristics of the mechanisms for making and implementing public policy in the Great Lakes Basin are first, the complexity of the institutional framework; and secondly, the fragmentation of power inherent in that complexity. A significant boundary for the purpose of ecosystem management is the outline of the Great Lakes Basin. Many people are astounded to learn that only a small portion of the land area of the region actually lies within the basin. Yet even that significant basin boundary is transcended by external influences. The discovery, for example, that water quality in the lakes is impacted by airborne pollutants carried great distances by natural atmospheric currents proves how difficult it is to draw geographical boundaries to our governmental concerns. The introduction of the sea lamprey into the Great Lakes was an unintended consequence of governmental decisions made far from the basin to subsidize and encourage private commerce.

In order to address the complexities of governance, one must identify international, national, state and provincial as well as local government bodies, all with bits and pieces of responsibility for human impacts on the functioning of the natural ecosystem. Four interjurisdictional agencies charged with coordinating activities of various governments will also be explored. Once the institutional outlines are sketched in, the need for integrative mechanisms can be addressed.

THE INTERNATIONAL SETTING

History teaches us that bodies of water have traditionally been viewed as convenient political boundaries. River, lakes and seas have been used for purposes of defense and demarcation, providing limits to settlements whether of communities or nations. So with the Great Lakes, four of which encompass an international boundary. The United States and Canada as sovereign and independent nations share possession of and responsibility for the water of the lakes. While Lake Michigan is not legally an international lake, being totally surrounded by U.S. territory, it is an integral part of the hydrological system of flows and levels. It has best been described as a cul-de-sac of Lake Huron; the waters flow downstream from Superior through Huron to Erie and Ontario, and into the St. Lawrence River on the way to the Atlantic Ocean.

Binational responsibility for the Great Lakes system was recognized and formalized by the Boundary Waters Treaty of 1909, in which Canada and the United States agreed to settle differences over allocation and use of boundary waters by negotiation. Domestic supply of water was given the highest priority, with navigation next in importance. Significantly, the two nations agreed to prohibit diversion of streams crossing the boundary, and not to pollute in such a way as to cause injury to the other nation, an early recognition of the major issues of today. The Treaty established the International Joint Commission (IJC) to carry out the provisions of the agreement. This binational authority was given actual decision-making power in limited areas of water allocation at the border. With respect to all other policies and actions, the IJC was given advisory power only. Its authority to investigate problems and recommend policy is limited to questions referred to it by the two sovereign governments in a formal "reference." This passive institutional character means that the only international body governing the Great Lakes is subject to two national wills.

The IJC is composed of six commissioners, three of whom are appointed by the Canadian government for fixed terms, and three of whom are appointed by the U.S. President, confirmed by the Senate, and serving at the pleasure of the President. While the Canadian mode of appointment emphasizes professionalism, the American method highlights politics and policy. This is only one of many differences between the two nations in governmental practices which hampers the effectiveness of a joint public enterprise.

However, most of the work of the Commission is carried out by binational boards staffed by civil servants "seconded" (or borrowed) from agencies of the respective governments. Such groups as the Water Quality Board, the Science Advisory Board, the Pollution from Land Use Activities Reference Group (PLUARG) are respected for the impartial and professional character of the studies they produce. Since the adoption by the two nations of the Great Lakes Water Quality Agreement of 1972, revised and renewed in 1978, these boards have persuaded the IJC to support an ecosystem approach to the management of the natural resources of the region. Implementation of its recommendations, however, remains within the sovereign power of the two nations.

Similar to the IJC in organization is the Great Lakes Fisheries Commission (GLFC), established in 1955 as a binational body to recommend means to manage the fish stocks of the lakes for maximum sustained productivity, and to eradicate the sea lamprey. Like the IJC, its research findings are accorded high respect, while its effectiveness depends on the commitment of the respective sovereign powers to carry out its recommendations.

THE SOVEREIGN NATIONS

Within the American government, responsibility for these matters is widely shared. Congress sets the broad parameters of public policy, but must secure executive assent. Action is often impeded by lack of agreement between President and Congress, or between the two houses of Congress. Delay in the renewal of the Clean Water Act is a case in point. The Renewal Act contains the much-discussed Great Lake Amendment, whose purposes include coordination of state and federal efforts to meet the standards of the Water Quality Agreement with Canada. Ironically, the Amendment remains in limbo because of lack of consensus among the multiple power centers of the American federal government.

Many departments of the federal government share implementation authority. Only the State Department may issue a reference to the IJC, since international relations are involved. Responsibilities for air and water quality, navigation, commerce and fisheries are shared by the Departments of State, Defense, Commerce, Interior and Transportation, the Environmental Protection Agency and other units scattered through the federal bureaucracy. The U.S. Army Corps of Engineers plays a key role because of its responsibility for maintaining the channels of navigation and for regulation of lake levels. The Corps co-chairs with Canada's Departments of Environment and Transport the Lake Superior and St. Lawrence River Boards of Control.

Not surprisingly in a nation where the practice of judicial supremacy is deeply rooted, even the U.S. Supreme Court is an ever-present decision-maker in the Great Lakes region. Under its original jurisdiction, where it sits as a trial court for disputes among the states, the Supreme Court regulates the amount of water that can be diverted from the system through the Chicago Canal. This diversion of Lake Michigan water, created in 1848 to protect Chicago's drinking water by flushing its sewage down the Mississippi River, has been litigated over the years by other affected states and is carefully controlled by the Supreme Court.

Interpreting the interstate commerce power of Congress under the U.S. Constitution, the Supreme Court acts under its appellate jurisdiction as well to shape state management of natural resources. For example, its famous 1982 decision, Sporhase v. Nebraska, 458 U.S. 941, declaring water to be an article of commerce and therefore beyond the absolute control of the states, has massive potential implications for the ecosystem management of the Great Lakes Basin.

In contrast, Canada's system of parliamentary supremacy concentrates power rather than dispersing it. The Canadian courts have little policy-making power, seldom exercising judicial review. Because the Prime Minister and cabinet are parliamentary leaders, there are no policy conflicts between executive and legislative initiatives such as are experienced in the U.S. External Affairs, Environment Canada, Transport Canada and the Department of Fisheries and Oceans are the principal Canadian federal agencies responsible for management of the region's activities.

WHAT'S LEFT FOR THE STATES AND PROVINCES?

Because both Canada and the United States are federal systems, their powers in the Great Lakes Basin are shared with two provinces (Ontario and Quebec) and eight states (Illinois, Indiana, Michigan, Minnesota, New York, Pennsylvania, Ohio, and Wisconsin). In both nations the navigable waters of the lakes are under federal jurisdiction, but the states and provinces own the submerged lands under their portions of the lakes. Beyond this similarity, there are significant differences between the two systems with respect to interjurisdictional relations. These differences will be discussed and illustrated by recent initiatives to overcome such institutional complexities.

Ontario's presence in the Great Lake Basin so outweigh Quebec's that there are few inter-provincial problems. But a cleaner line of demarcation between federal and provincial responsibilities is drawn in Canada, with environmental and natural resource responsibilities devolving more substantially on the provinces. For this reason, Canada uses more formal mechanisms to allocate responsibilities.

In Canada the constitutional framework clearly assigns environmental and natural resource responsibilities to the provinces. The Ministries of Natural Resources and Environment in Quebec and Ontario are dominant in such matters. In fact, in order even to negotiate an agreement with the U.S. about Great Lakes water quality, Canada first signed an internal agreement with Ontario to guarantee the implementation of terms to be negotiated externally. The Canada-Ontaria Agreement Respecting Great lakes Water Quality (COA) was first signed in 1971 and revised in 1976 and 1982. One of the key provisions of COA was the specification that only minimum standards of water quality would be binding on Ontario, leaving the province free to adopt more stringent standards if it so desires.

This provincial dominance contrasts significantly with the U.S., where Congress retains the pwoer to set maximum as well as minimum standards for compliance with environmental laws. Federal supremacy is a more powerful tool under the U.S. Constitution for the enactment and implementation of environmental policy. Although the Tenth Amendment reserves to the states those powers not delegated in the Constitution to the federal government, the dividing line between federal and state responsibilities is imprecise and permeable. Furthermore, that line is subject to judicial intervention in cases and controversies, as, for example, in the Sporhase decision mentioned earlier. Among the American states, responsibility is dispersed in a variety of ways. With eight state legislatures and governors at work to make and implement policy, different approaches to public issues inevitably develop. Partisan differences among the states reflect contrasting levels of commitment to governmental solutions of environmental and economic problems. For many years, however, on a bipartisan basis, the states have intermittently pursued interstate consensus on Great lakes issues through the Great Lakes Commission (GLC).

Organized by interstate compact in 1955, the Great Lakes Commission was not approved by Congress until 1968. This 13-year delay was caused by the states' plan to include the Canadian provinces of Ontario and Quebec in the Commission. Congress resisted this inclusionary approach because of reluctance to allow states to conduct foreign relations. When the states withdrew their insistence on a binational regional approach, Congress ratified the compact.

The purpose of the GLC is "to promote the orderly, integrated, and comprehensive development, use and conservation of the water resources of the Great Lakes Basin." Headquartered in Ann Arbor, Michigan (the only state lying totally within the Basin), the Commission has quietly addressed both environmental and economic issues, particularly the welfare of lake shipping. While the Commission can adopt issues by majority vote, its role remains advisory to the states.

The Commission's structural weakness lies in its lack of authority to act: it is not a supra-state, regional government. Mehtods for choosing its members (3 to 5 commissioners from each state) are designated by state statute, with at least one appointed by the Governor of each state. The variety of selection methods and provisions for accountability to the respective states leads to differing degrees of state commitment to this interstate enterprise. Even under this limited authority the Commission has never exercised its total potential of regional advocacy and coordination of policy.

A relatively new and rapidly evolving regional institution is the Council of Great Lakes Governors (CGLG), formally established in 1982 by the governors of six states (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisocnsin). New York, Pennsylvania, Ontario and Quebec participate as voting members of the Council's committees. The Council's rise to prominence in the 1980s and its significant achievements demonstrate how political leadership can reduce the impact of institutional fragmentation. Although the Council, like the Great Lakes Commission, lacks the authority to implement its recommendations, the Governors have provided a dramatic focus for addressing policy issues in several key areas.

The Great Lakes Charter, signed in 1985 by eight governors and two premiers, marked a historic breakthrough in interjurisdictional cooperation. The states and provinces agreed on consultation and cooperative management of the water resources of the Great Lakes Basin to prevent damaging diversions and consumptive uses. Under the leadership of Governor Anthony Earl of Wisconsin, Chairman of the Council of Great Lakes Governors, the Council's Task Force on Water Diversion and Great lakes Institutions worked its way through the institutional maze to develop an integrated approach to water quantity problems which respected the legal and political diversity of the many governments involved. The Charter is non-binding for legal and constitutional reasons which have already been discussed, but the good faith of the signatories is demonstrated by the prompt establishment of a working group of technical experts to develop a common data base on current uses of the region's water supplies.

Little more than a year later, another landmark interstate commitment to manage the lakes as an integrated ecosystem was made. In May, 1986, a Toxic Substances Control Agreement was signed by the governors of the eight Great Lakes states. Because this agreement was formulated within the framework of U.S. regulatory law, the premiers did not sign, but expressed their support for the plan and promised to issue a similar official commitment to toxic cleanup by October 1. A key feature of this Agremment is the explicit determination to deal with the movement of pollutants through the system: in the air, in surface water and in ground water. Not only are common goals defined, but specific actions accompanied by deadlines are agreed upon for implementation.

The effectiveness of these bold regional measures clearly depends on the ability and will of the individual states and provinces to develop and pursue management plans, both for water quantity under the Charter and for water quality under the Toxic Substances Control Agreement. Here again, institutional diversity takes over.

It is difficult to generalize about the structures of governance within the states beyond the commonality of the separation of powers into executive, legislative and judicial branches. Within the state bureaucracies, agency responsibilities differ. Typically, however, parks and recreation, water planning, wildlife and fisheries management and coastal zone protection are allocated to Departments of Natural Resources, while air, water and land pollution control is assigned to state Environmental Protection Agencies. Significant overlap of duties may result, as when land uses degrade the quality of water in coastal wetlands and affect fish habitat.

Even within a single department, conflicting goals may present management challenges. For example, within Departments of Natural Resources, expansion of shoreline parks for recreational use may undermine efforts to preserve the remaining wetland areas. Public policy is difficult to make and even more difficult to implement under these pressures. Efforts to overcome intrastate fragmentation have been made in states such as Ohio where in 1984 Governor Richard Celeste appointed an interagency committee on water to coordinate policy initiatives and to prevent duplication of effort . The "Water Cluster" is composed of cabinet directors of Natural Resources, Environmental Protection, Health, Agriculture and Transportation. Its first responsibility was to develop a strategic plan for the state's natural and physical environment. Its attention is now directed to ground water planning.

THE GRASS ROOTS

The institutional labyrinth which has been described from state to international levels is not yet complete. There is yet another maze of overlapping governments to be taken into account in the region: the local level. Although the impact of each local government may be small, taken together the decisions of counties, municipalities and special districts are consequential indeed. Soil conservation districts may affect amounts of non-point source pollution. Municipalities or special sewer districts are responsible for wastewater treatment. Erosion from construction sites and other urban runoff into tributary streams are local matters. Counties bordering the lakes may perform solid or liquid waste disposal functions.

Generally land use planning is a local governmental function on both sides of the international boundary. There are few more fervently protected local powers than planning and zoning. Here indeed is government that is close to the people. Subregional attempts to coordinate land use planning among communities are often resisted as unwarranted intrusions on local autonomy. These are political culture attributes which create the fragmented base for all other governmental attempts at coordination of policy.

No comprehensive inventory is available for local governmental units in the Great Lakes Basin, but the numbers are in the hundreds. These decision-making entities are critical for the over all management of the region's ecology, yet they deal with significantly differing local conditions and operate under the eagle eyes of local residents whose preferences are driven by a multitude of private motives. In some instances, the nations, states and provinces can mandate action by these local authorities, or can induce them to act by providing significant financial incentives. What the higher authorities cannot do is to stay with the local governments for every step to ensure compliance. Some degree of cooperation from below is necessary if regional goals are to be attained.

CONCLUSION

This brief survey of governmental complexity in the Great Lakes region has identified the roles in resource management played by two nations, provinces, eight states, four regional institutions and hundreds of local governmental units. In the 1980s a significant breakthrough has occurred in public awareness of the inestimable importance of the vast freshwater system we appropriately call the Great Lakes. Support for environmental values is rising, and in the Great Lakes region this includes an appreciation both of water supply and of the quality of that water.

The surge in public interest and concern is reflected in the creation of new private organizations such as Great Lakes United and the Center for the Great lakes, the former for advocacy and the latter for research and policy development. These groups offer expertise and encouragement to policy-makers to act aggressively to develop management strategies for repair of the damage human beings have done to the system, and for sustainable resource use in the future.

Some experts (e.g. Milbrath) have argued that we need to create new institutions for regional management of this precious resource. Others (e.g. Donahue) find existing institutions underutilized and advocate "building new relationships among existing institutions" (Great Lakes Basin Framework Study, 1975).

"Political will," Donahue writes, "is <u>the</u> overriding determinant of the success of a given regional institution. When present, it can transcend even the most restrictive insitutional form. When absent, even the most innovative form can become impotent" (Donahue, SAFR, 1985).

The sense of urgency which is widely felt today grows out of perceived crises: the threat of water supply depletion if arid regions should use their political power to divert the lakes' water to the south and west. These particular crises may be dealt with in the next decade, but it is of vital importance to educate future generations to care about the lakes for the long range so that we need not go through alternating cycles of intense activity and indifference, crisis and neglect. As teachers and concerned citizens we need to nourish sustained attention and active concern for the ecosystem.

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THE ROLE OF THE MEDIA IN PUBLIC PERCEPTION OF LAKE ERIE

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A 1965 article in Newsweek, entitled "Great Lakes: The Dead Sea," began "To live on Lake Erie is to know the stink of algae and dead fish." A year later, Science News in an article about "The Dying Lake" claimed, "This is Lake Erie -- a wasteland, a lifeless body of water that has lost its sparkle and vitality, and is being hastened to its wretched fetid death by man's affluent wastes and increasing activities." Lake Erie was the national symbol for water pollution during what is popularly called the environmental movement of the 1960s and '70s.

The mass media are frequently given credit for bringing the pollution problems of Lake Erie the public attention that ultimately resulted in remedial action for lake cleanup. At the same time, patterns of media coverage of Lake Erie issues over the years have resulted in a public perception that remains negative even in the face of vastly improved environmental quality.

This study looks at the role the media play in influencing public opinion on environmental issues. Such considerations necessarily include how the public accepts media information, what the content of that information has been, and what media tactics have been used for its presentation. The literature of environmental communications will serve as the basis for this preliminary discussion. Subsequently, the chronology of media coverage of Lake Erie will be reviewed, with specific examples from newspapers, magazines and television. The study will conclude with a consideration of what can be expected from the media in coverage of Lake Erie today.

I. How do the mass media influence the public?

Mass media serve an agenda-setting function for public attention. Basically this means that by the choice of what to print or broadcast, the media decide for us the topics that should be of greatest concern at any given time. The media have only a limited "news hole," that part of the newspaper that isn't filled with advertising or regular features, or that length of time available on the evening news or drive time broadcast. Thus a strong selective judgement must be exercised by a person or group within these media to decide what is really newsworthy. This person or group, known as the "gatekeeper," chooses the messages the public is to receive.

Because of the limitations of the news hole, an issue that gains public attention through the media causes another issue to lose attention. For environmental issues to receive expanded coverage in the late 1960s, coverage of civil rights issues declined. Environmental concerns, in turn, were largely replaced in the mid-'70s with the energy crisis, which the media portrayed more as an economic issue than an environmental one.

II. How do the media cover the environment?

For most of our history the environment has not been a genuine news topic. "Real" news is hot, eventful, characterized by crisis or personality. Rarely does the environment fit these descriptors. Things usually happen gradually and quietly in the environment. For environment to become news requires a Love Canal, a Cuyahoga River bursting into flame, or a Jane Fonda to lead a march against nuclear waste disposal siting. In the absence of such events, a pseudoevent may be devised to garner attention, or an extreme statement may be put forth as a gripping if not entirely accurate headline.

Environment has been a difficult topic for the media. The topic is sometimes treated superficially, mostly because of space limitations or lack of science training and understanding of issues among environmental reporters. There are no standard information sources for such a reporter, because every issue has its own science and social consequences. Sometimes the information sources available have good reason to camouflage the truth, and the training of a typical reporter does not equip him or her to detect this. The environmental story is rarely a visible one or one that is a single subject, for in the environment everything is related to everything else. As Roberta Hornig of the Washington Star has noted, "every story is like taking a college course."

As for space limitations, most of the news hole for the entire period of the environmental movement was filled not with environment but with the Vietnam war. Vietnam was everyone's local issue because of the extent of U.S. military involvement; environmental quality, especially Lake Erie's, was not local nor immediate for very many people. A search for Lake Erie references in television news archives of 1966 revealed that almost half of every NBC half-hour nightly news program was devoted to Vietnam or related subjects. On a local level, however, the Cleveland Press coverage of Lake Erie problems was outspoken and ongoing, utilizing the news hole available as well as editorial and feature space.

The environment began to appear with measurably greater frequency in the media in 1965. For Lake Erie, that year marked a campaign by a prominent Cleveland businessman through the Cleveland Press to "Save Lake Erie Now." Environmental coverage increased in the 1960s to a peak in 1970, a year which featured Earth Day and the beginnings of implementation of the National Environmental Policy Act. In some media, notably specialty magazines, the amount of coverage continued to rise through the middle of the 1970s, but for the most part environmental coverage declined rapidly into the '70s.

III. How has the public responded to media coverage of the environment?

Surveys indicate that the public basically trusts mass media information. People also frequently acknowledge mass media, especially television, as a major source of environmental information.

According to media analysts, media coverage of the environment has gone hand in hand with increasing public concern about environmental quality. During the peak years of environmental coverage by the media pollsters found that the public evidenced a growing concern about environmental quality. This in itself does not imply a cause and effect relationship, of course, but a few studies have documented that high levels of environmental concern have followed specific media events. The television documentary on The Wolf Men, for instance, generated 16,000 letters from the public in support of protection of endangered species. The efforts of the Cleveland Press are credited with convincing Ohio's Governor James Rhodes to request of the U.S. Secretary of Health, Education and Welfare that a conference on Lake Erie water quality be convened. That conference resulted in a five-state pact with the Federal Government to work for the improvement of the lake.

There is no question, then, that the mass media helped establish the environment as an issue, and Lake Erie was a part of that issue. Specific examples of media coverage and public response constitute the remainder of this study.

IV. What have the media told us about Lake Erie?

Early Communications.

The earliest writings about Lake Erie appeared before white settlement. For example Gallinee, a French voyageur, wintered in the Port Dover area in 1669-70. His writings extolled the resources of the area thus:

> "I leave you to imagine whether we suffered in the midst of this abundance in the earthly Paradise of Canada, I call it so, because there is assuredly no more beautiful region in all Canada. The woods are open, interspersed with beautiful meadows, watered by rivers and rivulets filled with fish and beaver, an abundance of fruits, and what is more important so full of game that we saw there at one time more than a hundred roebucks in a single band, herds of fifty or sixty hinds, and bears fatter and of better flavor than the most savory pigs of France."

As for the Lake itself, it was described later for its clarity and abundance of fish:

> "The small boat was rowed around the islands, whilst we cast our lines... In a short time we caught upwards of five dozen black bass -- weighing from four to six pounds. The lake water is so clear that fish can be seen from twelve to fifteen feet below the surface. Many of the fish we saw advancing to our hooks." (describing the Western Basin in 1804)

During the early part of the twentieth century, Lake Erie and the islands were a popular resort:

> "When summer comes, the land is bright and the region quickens. The cottagers and campers move into their lake-shore homes; the resorts and beaches are suddenly crowded with fun-seekers; the highways are thick with

automobiles. Wherever you look, there is a fisherman, armed with rod and reel or the common bamboo pole. Out on the bay and lake, pleasure craft flash and scud across the waters with beautiful abandon. Breezes from the lake soften the heat of the sun's bright rays. Over the region hangs a gay and infectious buoyancy.

Vacationland has come into its own. 'The season' is at hand." (Ohio State Archaeological and Historical Society, 1941)

Impact of Development.

Early in pioneer days the problems that foretold Lake Erie's future water quality began to appear. The life of the pioneer was a difficult one. Burns (1985) claims that the continual struggle against the elements gave people a concept of nature as the enemy that had to be conquered. In the conquest, abuse of nature was common. Harlan Hatcher (1945) commented on what the Detroit waterfront was like in 1820:

> "Our pioneer forefathers took little thought for the waterfront of their towns on the rivers and lakes; their interests were utilitarian and, in too large a measure, their views have prevailed into our time. The riverbank, which drew from Cadillac a prose poem of admiration for its beauty, was a dumping place for refuse and dead and rotting animals."

As the importance of the Great Lakes as a route for commerce became more apparent and shoreline development ensued, the lakes continued to be imperiled by those they served. As early as 1860, Cleveland was experiencing taste and odor problems with its water supply, which it drew from Lake Erie. Industries were clustered along the shoreline for transport of raw materials and finished products, and for water to fuel and cool the industrial processes. Waste products dumped into the water were quickly flushed away to unseen downstream regions, so it was easy to become deluded that there was no real problem.

The Black (or Green) Era of Communications.

The nutrients whose effects have been described by Herdendorf (1986) have encouraged increased algal growth and resultant oxygen depletion during Lake Erie summers. The historical records of the Cleveland Waterworks indicate that there was a marked increase in the number of algal cells in Lake Erie water beginning in 1927, with accelerated growth beginning in 1960. Public information sources before 1960 contained no documentation of this, however. The data were apparently important only to the record keepers at the Waterworks.

Early voices of alarm were few. Scientists took due note of the disappearance of the mayfly, but the public at that time was not interested in ecology. Robert C. Drake, science and nature writer for the Cleveland Plain Dealer, attempted in 1959-60 to alert the public to changes occurring in Lake Erie and "prod government out of its lethargy." The Plain Dealer published Drake's research as a magazine supplement, but the topic was not seen in the early '60s to warrant continuing daily coverage. Had the Cleveland papers served as initiators of interest or educators of the public to a new problem, they could have been in the vanguard of environmental reporting. Newspaper editors do not often select such a role.

Then the algae growth became a visible scum. In 1964, widely disseminated news media carried photographs of an algal bloom that covered "an 800-square mile area of western Lake Erie with a green scum."

The year 1965 marked the first major outpouring of public sentiment for saving Lake Erie. As has been common in environmental reporting, the news media provided two main types of reports during that time, the gloom and doom reports of the dying lake, and the industrial successes in cleanup. Newsweek's "The Dead Sea" (April 12, 1965) reported that "In a 2,600-square-mile area, more than a quarter of the lake, useful water life has already been smothered." Business Week, on the other hand, was reporting that "Business and local governments agree with surprising ease to help halt pollution of Lake Erie, despite huge costs" (August 14, 1965).

By the summer of 1966 Erie's pollution was still hot news, with the same two approaches being used by journalists. For the next few years environmental quality in general was a topic for media attention, and most news magazines as well as general interest publications such as Saturday Review and Sports Illustrated carried feature articles about the source of Lake Erie's problems and what was being done. A listing of major articles appears in the references, but selected ones deserve special note.

Saturday Review for October 23, 1965, carried a short but positive article about progress in saving Lake Erie and the importance of that progress for the entire nation. A feature article in the same magazine on September 20, 1969, however, was entitled "Life on a Dying Lake." While its first page was one of the typical gloom and doom pronouncements, further reading, if such was pursued, revealed a more poignant story of the lake's changes and the people on its Cleveland shores. Still, some paragraphs apparently intended to attract attention could have contributed to readers' perception of a lake whose condition was so bad it was ludicrous:

> "On the Cuyahoga River, twice each day, the excursion boat Goodtime II takes tourists on a run of the industrial sites; a tape-recorded spiel piped over the Goodtime's loudspeakers describes the adjacent activities of the Great Lakes Towing Co., U.S. Steel, Republic Steel, Sherwin-Williams Paint, National Sugar Refining, and Standard Oil. (No word about waste discharges, about the phenols and oils and acids that ooze into the river. 'If you fall in,' they say along the river, 'you won't drown, you'll decay.') On summer evenings at the foot of the river, on the flats off Front Street, the customers of Fagan's Beacon House sit at their tables just above the ooze listening to Dixieland, drinking beer, and watching the

ships go by. It is, they say in Cleveland, one of the places 'where everybody goes.'"

To the magazine's credit, a 1970 issue carried John Sheaffer's article on "Reviving the Great Lakes," indicating in it that "the calamitous news [of Lake Erie's death] should not be accepted as the final word." The article advocated the use of sewage as fertilizer for inland farms in order to reduce the input of nutrients to the lakes.

Harper's for August 1972 carried a frequently quoted article by Patrick Young, "A Modest Proposal." This article introduced the proposal of Frank Ogden, Ontario College of Art, to drain Lake Erie. "Lake Erie is a cesspool and it's beyond hope," Ogden is quoted. "So let's turn defeat into something positive for the area." He envisioned the basin becoming new acreage for cities, farms and recreation areas, as well as a tiny nation that would be the new home for the U.N.

Science Reports.

For those who read original science documents, relatively objective literature was abundant. Science carried at least two articles during the period (see References, Part B) and technical reports and government documents were abundant. The references provided by Great Lakes Symposium speakers provide a valuable resource on information available regarding specific lake characteristics over time.

Lake Erie in the School Library.

For the student in the sixth grade who was assigned a term paper about Lake Erie, a number of notable references were available in the average school library. The first choice of any student, World Book Encyclopedia, contained Barry Commoner's "Lake Erie, Aging or Ill?" in its 1968 Year Book. Its first paragraphs set a tone that unfortunately was negative, but fortunately did not continue in as heavy a vein throughout:

> "Lake Erie is becoming a wasteland. Listless waves lap along its shore, sucking in and out among the slimy green rocks, deserted beaches, and oily pilings of seldom-used piers. ...The variety of floating and rotting wastes is a constant reminder that man can indeed kill a lake. ...Some even say the lake is dying so fast it will soon be an aquatic desert -- America's Dead Sea."

For the greater part of this article Commoner presented factual information about the aging of lakes and the changes that had been documented in Lake Erie. His voice was heard often in the height of the environmental decade, and occasional notes of extremism were consistent with other voices of the time. A religious-like fervor characterized many. The urgency of Commoner's message, more than the actual choice of words, is likely to have made this World Book article and its reprint in Scientist and Citizen magazine an important source of information for many adults as well as students.

Other information sources available to the sixth grader included a series of children's books on pollution that appeared during the late 1960s and early '70s. Pollution: The Waters of the Earth was typical of the worst scare tactics and emotional, uninformed writing that appeared during the period. Unfortunately, students are frequently not trained in critical reading skills and often accept the nonfiction library book as the ultimate source of truth. Thus a chapter entitled "TRUE MURDER STORIES: So Long, Lake Erie," would likely serve uncontested as the information for the term paper. Such books are still on school library shelves serving this function.

On the other side of the school picture was the Man and the Environment textbook for life science, which provided a major student investigation to determine "Is Lake Erie dead?" Students read that

> "Today Lake Erie has become a symbol of water pollution. The newspapers and magazines say, 'Lake Erie is dead,' and 'Lake Erie is a big open sewer.' They may have exaggerated the facts. They may want to scare people into stopping the pollution."

In the activity actual databases of different types were provided for background information to allow students to synthesize an answer to the question. The teacher guide provides further encouragement for leading objective discussions of media reports, given the facts available.

A final note on children's literature about Lake Erie: Dr. Seuss' The Lorax contains a comment by the Lorax as part of his indictment of the environmental havoc wreaked by the Onceler. The humming-fish are leaving their pond because the water is "so smeary. I hear things are just as bad up in Lake Erie." The timeless nature of a Seuss book is altered here by a reference that is no longer correct. Our office staff wrote to Dr. Seuss, who indicates that future issues of The Lorax will not have the negative reference to Lake Erie like the 1971 original.

The Role of Broadcasting in Providing Lake Erie Information

National Public Radio has been providing objective information about Lake Erie and the other Great Lakes for over ten years, and studies have shown that awareness of resources can be increased through brief radio exposures. NPR broadcasts frequently deal with specific topics such as toxic substances, with exquisitely balanced coverage of all sides of issues. No studies are available specifically regarding their effects, but the prospects are promising based on previous research. Radio programmers in England have likewise done an audio documentary featuring James P. Barry and his objective perceptions of the status of Lake Erie enviornmental quality.

Surveys of students and adults frequently reveal that people see television as their major source of environmental information. It has already been noted that television news during Lake Erie's worst period was dominated by the Vietnam war. A number of documentaries were televised, however. WBBM-TV in Chicago (CBS) produced Too Thick to Navigate, Too Thin to Cultivate. This was followed by an NBC White Paper report on Who Killed Lake Erie? While both presented the facts about the sources of water quality problems and realistic prospects for clean up, their initial tone and occasional lapses into emotionalism probably influenced millions of viewers in attitude formation as well as providing a memorable visual image of selected examples of ugliness. Their titles alone had a quotable quality that was used frequently afterwards.

Since the early 1970s Lake Erie has not received much attention from the television medium. Unfortunately the only network coverage that made news was a question by Johnny Carson: "Lake Erie -- isn't that the place where fish go to die?" This is a prime example of public perception that has persisted into this decade for lack of information to the contrary.

A number of universities have produced video programs that have appeared locally, some on specific topics, such as Cleveland State University's The Lake at Our Doors, and some more general regarding politics anad economics of the region, such as the University of Michigan's The Great Lakes: Our Joint Heritage. Environmental interest groups have videotaped their conferences and public debates for a number of other local showings (e.g. Basin Without Boundaries, 1986, produced by the Center for Environmental Studies).

Modern Communications About Lake Erie

The 1980s have seen few media productions devoted specifically to Lake Erie environmental quality, and decreased levels of media coverage are typically accompanied by a drop in public perception of an issue's importance. Today's issues are toxic substances in the Great Lakes, diversion of Great Lakes water to other parts of the country, and high water levels with their impact on coastal property owners. Media attention has been focused on political activity, with the Great Lakes Charter of 1985, an unprecedented document for regional agreement on use of Great Lakes water, being supplemented in 1986 by a toxic waste agreement among the Great Lakes governors.

One notable exception to the lack of doomsday reports in recent history is a 1986 book entitled The Late, Great Lakes. In it author William Ashworth assumes the old emotional tones and unremitting negative reports of the impending demise of the lakes. While the book is an excellent resource on the region's history and contains interesting anecdotes about politics and development, readers are never allowed to forget that the good old days weren't all that good and the worst is yet to come. It is unfortunate that the remarkable improvements in environmental quality have been minimized while the author predicts the worst for our regional future.

The news media, while they have never covered the clean-up of Lake Erie in any comprehensive fashion, no longer refer to dead lakes, stenches, and green scum. Instead, Lake Erie is again a resort area, part of the North Coast that welcomes vacationers and new residents with the same bright sun, crowded marinas and rows of condominiums that characterize the other coasts. The question now is "Will success spoil Lake Erie?" (Capitol Magazine, July 7, 1985).

V. What can be expected of media coverage of Lake Erie in the future?

Good news, gradual growth, optimistic developments and positive actions by hard working people rarely make headlines, but these are the things that characterize Lake Erie's environmental quality today. There are still problems, of course, but unless they become calamities it is unlikely that they will receive much media attention.

In the meantime, those who encounter Lake Erie in person for the first time will be surprised, first at its magnitude, and second at its beauty. The Lake is a natural resource of gigantic and diverse importance. That perceptions now must evolve slowly as media attention lags is unfortunate. Perhaps public perception, like Lake Erie, is at a point of balance, on the verge of emerging from a dark past into a bright future.

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